Earthlike planets aren't as rare as you think p. 34

NEW! Inside buzz: Astro Confidential p. 10

April 2009

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WHY THE UNIVERSE HAD NO BEGINNING

The **Big Bang** may not have been the instant of creation, but a single event in an infinite cycle p. 28

Find your way through the spring sky p. 54

Is the **Big Bang** in trouble? p. 48

HYPERSTAR: Lens system allows quicker imaging p. 62

If we live in a cyclic universe, the galaxy-rich cosmos we see today happened before and will happen again in an infinite cycle created by colliding "branes."

PLUS!

HOT PORTFOLIO: New galaxy shots, Milky Way panoramas, and star clusters p. 56

Bob Berman on why astronomy setbacks may be good p. 16

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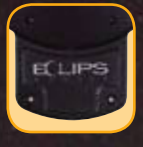

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We will announce the contest winners and feature their images in the September issue.

Astronomy magazine

Contest rules

Please submit digital images online at www.Astronomy.com/photocontest. • You can also send images on a CD or DVD to: *Astronomy* Photo Contest, P.O. Box 1612, Waukesha, WI 53187-1612. • The image must feature an astronomical subject in one of the three categories: Deep Sky, Solar System, or General. • One entry per contestant. • Composite images (those made from multiple exposures) are allowed. • Please include a description of the subject featured, the name and address of the imager, equipment used, and exposure time(s). • All entries must be submitted by April 15, 2009. • No images/disks will be returned. • If *Astronomy* selects non-winning images for publication, we will pay submitters at normal rates. • Judging will be conducted by the *Astronomy* staff. • Kalmbach Publishing Co., Rancho Hidalgo, and Arizona Sky Village employees and their families are not eligible to enter this contest. • Cash payout will be awarded following the completion of your stay at Rancho Hidalgo. Travel arrangements to and from Rancho Hidalgo are the responsibility of the grand prize winner, who will need to arrange a time with the Rancho Hidalgo/Arizona Sky Village staff.

Deep-sky images: NASA/ESA/Hubble Heritage Team (STScI/AURA); Moon image: Lick Observatory; Arizona Sky Village photo: Michael E. Bakich; Model with telescope: *Astronomy*: William Zuback

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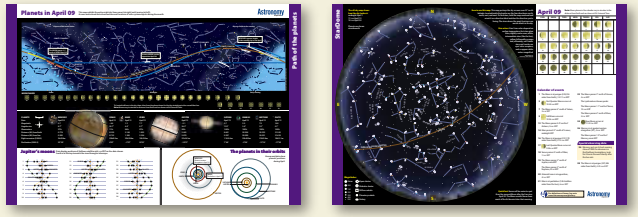


Path of the planets and StarDome.

Astronomy
WHY THE UNIVERSE HAD NO BEGINNING
Find your way through the spring sky
Is the Big Bang in trouble?
HYPERSTAR: Lens system allows quicker imaging

ON THE COVER

The Cigar Galaxy (M82) is a shining example of what our universe can create. If we live in a cyclic universe, however, our galaxy-rich cosmos has happened before — and will happen again.

Cover: NASA/ESA/The Hubble Heritage Team (STScI/AURA)

8 This Month in *Astronomy*
Welcoming David Levy to *Astronomy*'s team.

10 Astro Confidential
Lisa Randall
Ann Hornschemeier
Matt Mountain
David Helfand
Lisa Frattare

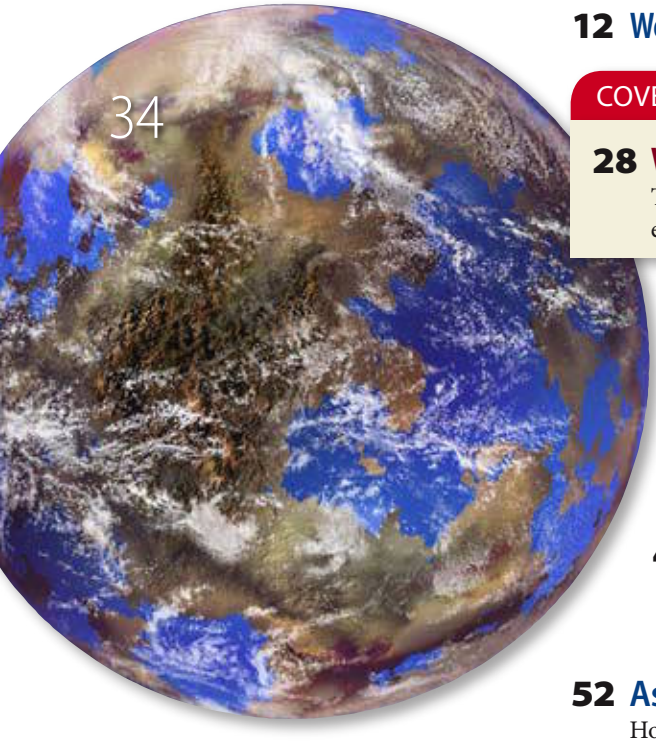
12 Web Talk

14 Letters
Stellar order.

16 Strange Universe
Major mess-ups ... maybe. **BOB BERMAN**

18 Secret Sky
Searching for shadow bands.
STEPHEN JAMES O'MEARA

20 Astro News
Methane reveals Red Planet's active innards.
New evidence backs dark energy.
Milky Way's central black hole gets weighed.



COVER STORY

28 Why the universe had no beginning
The Big Bang may not have been the instant of creation, but a single event in an infinite cycle. **PAUL J. STEINHARDT**

34 Is Earth one of a kind?
Ten years ago astronomers thought our planet was really, really special. New observations suggest it may not be so rare. **RAY VILLARD**

40 The Sky this Month
Mercury meets the Pleiades.
MARTIN RATCLIFFE AND ALISTER LING

48 Is the Big Bang in trouble?
The cosmologists who explained how our universe came to be now face their greatest challenge: proving exotic fundamental concepts like dark matter and dark energy. **DANIEL PENDICK**

52 Ask Astro
How stars orbit inside clusters.

54 Find your way through the spring sky
Warm weather and giant constellations beckon beginning observers. **MICHAEL E. BAKICH**

56 Chris Schur captures the universe
Detailed galaxy shots, Milky Way panoramas, and gleaming star clusters showcase this skyshooter's best work. **CHRIS SCHUR**

62 With HyperStar, you'll image more in less time
After a quick alteration, you can produce great images up to 30 times faster. **JACK NEWTON**

66 Observing Basics
A swarm of stars.
GLENN CHAPLE

67 Advertiser Index

68 Binocular Universe
Comb through Coma Berenices.
PHIL HARRINGTON

70 New Products

74 Telescope Insider

76 Reader Gallery

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Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement # 40010760.

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Welcoming David Levy to *Astronomy*'s team

by David J. Eicher

In January 2009, world-renowned amateur astronomer and comet discoverer David H. Levy joined *Astronomy* magazine as a contributing editor. David will write a monthly column for the magazine starting in the June 2009 issue — the column will focus on a wide range of topics that will underscore the human aspects of amateur astronomy and everything that goes with it. I'm sure you'll be delighted with the stories David will bring you.

The famous astronomer is noted for discovering 22 comets over his long career, including the co-discovery of Comet Shoemaker-Levy 9, which broke apart and slammed into Jupiter in 1994. He is the author or editor of 35 books and products, has served as the science editor for *Parade* magazine, and has written for most of the popular astronomy magazines in existence, including *Sky & Telescope* and *Deep Sky*.

David Levy with Obadiah, his largest automated telescope. Wendee Levy

David also won an Emmy for his 1998 participation on the writing team for the Discovery Channel documentary *Three Minutes to Impact*.

Anyone who has been around for a long time as an amateur astronomer knows how entertaining Levy is as a speaker. He has given more than 1,000 lectures and popular astronomy talks, and has appeared on a wide variety of television programs to promote astronomy, including *The Today Show*, ABC's *World News Tonight*, and *Good Morning America*. Levy is the recipient of five honorary degrees from various institutions.

He lives with his wife Wendee in Vail, Arizona, where they operate the Jarnac Observatory, surveying the sky for comets and promoting astronomical education.

Astronomy is especially proud to add Levy to a distinguished group of popular columnists that includes Bob Berman, Glenn Chaple, Phil Harrington, and Stephen James O'Meara.

This development is especially pleasing to me, as I've known David since I was a teenager publishing *Deep Sky Monthly*, my boyhood project, to which David contributed.

Speaking of that, I'm happy to announce that, for the first time, issues of *Deep Sky* (*Deep Sky Monthly*'s successor) and *Telescope Making*, the quarterly magazines published by *Astronomy* in the 1980s and 1990s, are now available online as PDFs. You can access the first few of each as electronic downloads — soon, all of them will be available. To see them, please check out http://kalmbachcatalog.stores.yahoo.net/astronomy.html.

On a final note, I'm excited to announce *Astronomy*'s 2009 astrophoto contest, which offers prizes for imagers in several categories. Please see our notice on page 5 of this issue for full details.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 37, Number 4

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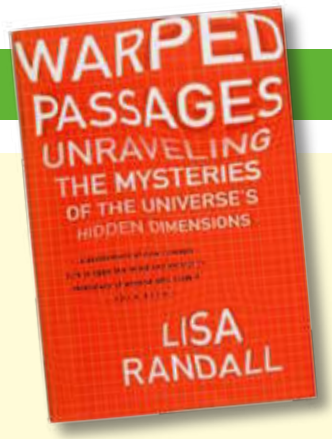


What got you interested in hidden dimensions — those that go beyond the three dimensions of space we can see?

I didn't start off interested in what would have seemed like a wacky science-fiction topic when I first entered the field of particle physics. I was interested in questions that I thought might have some relation to what is seen in the universe.

Many years after I entered the field, these interests converged in the subject of extra dimensions. We now have ideas about how extra dimensions can explain some perplexing puzzles that are difficult to address in a world with only three dimensions of space. We don't yet know if these ideas are the correct description of the world, but they are suggestive and promise some elegant solutions.

On February 13, 2008, you appeared on *The Colbert Report*. What was that like?

It was fun. The people were very professional — careful to prep me and studious about the interview's logistics. (Stephen's comment after it was over was, "Nice interview, but we'll have to cut 20 seconds.") The only thing I regret is taking seriously their advice to not be funny — even though it was probably good advice!

Where do you see yourself in 5 years?

In some respects, I will be in a similar place to where I am now: thinking about difficult questions in particle physics and cosmology — how to connect fundamental theoretical ideas with the superficially mysterious phenomena that we observe in the universe.

By then we should have more data, so I'll have new stuff to explain and many new clues about the right directions to be thinking about, both from the Large Hadron Collider (LHC) and a number of astronomical and cosmological missions that are out there observing the universe.

"It's exciting that there are facts about the world out there that we can discover."

Why do you feel cosmology and particle physics are important?

I believe it's important to know there is something larger than ourselves and something more permanent than what I ate for dinner today. It's exciting that there are facts about the world out there that we can discover.

And, of course, in the process of asking and answering difficult questions and making discoveries, people have changed the face of the world we live in — usually in entirely unforeseen ways.

Astrofascinations

What fascinates you most about multiwavelength astronomy?

Ann Hornschemeier

Astronomer at NASA's Goddard Space Flight Center Laboratory for X-Ray Astrophysics in Greenbelt, Maryland

I describe myself as an X-ray astronomer, but I think we're coming to an era where such a narrow label will be inadequate.

Today, an army of people is studying star formation in galaxies. X-ray astronomy is just one specialty that enables a multiwavelength attack on the big astrophysical questions of our time. For example, the starburst galaxies I study emit most of their radiation as infrared, visible, and ultraviolet light. Because the X-ray emission is relatively weak, I must depend on multiwavelength data to place the measurements into proper context.

It's amazing that we can take a census of X-ray binary systems in star-forming galaxies up to 8 billion light-years away. Coupling this information with the more plentiful data at other wavelengths helps astronomers learn how stars form and die.

We must work with experts who know how to use the data-analysis tools for specific wavelength bands and instruments. Different techniques ensure that people come from a diverse set of scientific backgrounds, which keeps the astrophysics discussions interesting.

Multiwavelength astronomy combines the best-available data in every part of the spectrum to show us what is really going on in the universe.

8,000,000,000

The light-year limit for taking a census of X-ray binary populations in galaxies.

A DAY IN THE LIFE OF ...

Matt **Mountain**

Director of the Space Telescope Science Institute in Baltimore

8 A.M. First scan of news and NASA gossip sites and a harder look at e-mail. "Meditate" on what I'm going to say at this morning's opening session of the International Virtual Observatory Alliance Interoperability Workshop that the institute is hosting this week.

10:10 A.M. See the imminent press release announcing the first direct image of a planet that the Hubble Space Telescope (HST) made some months back. Arrive at "tag-up" with the HST mission team 10 minutes late.

11 A.M. Weekly "tag-up" with the James Webb Space Telescope (JWST) mission team.

1 P.M. Switch to "Administrator mode" — discuss medical costs and federal auditing procedures. Look at next week's travel schedule: California, Washington, D.C., Goddard Space Flight Center, and the Maryland Space Business Round Table.

3:30 P.M. Run downstairs for weekly visiting colloquium speaker.

4:30 P.M. See the latest "widgets" our folks have put into our collaboration with Google, *Sky in Google Earth*.

5 P.M. Meeting about our study on a potential next-generation telescope beyond JWST (call it the "Next Big Thing" [NBT]).

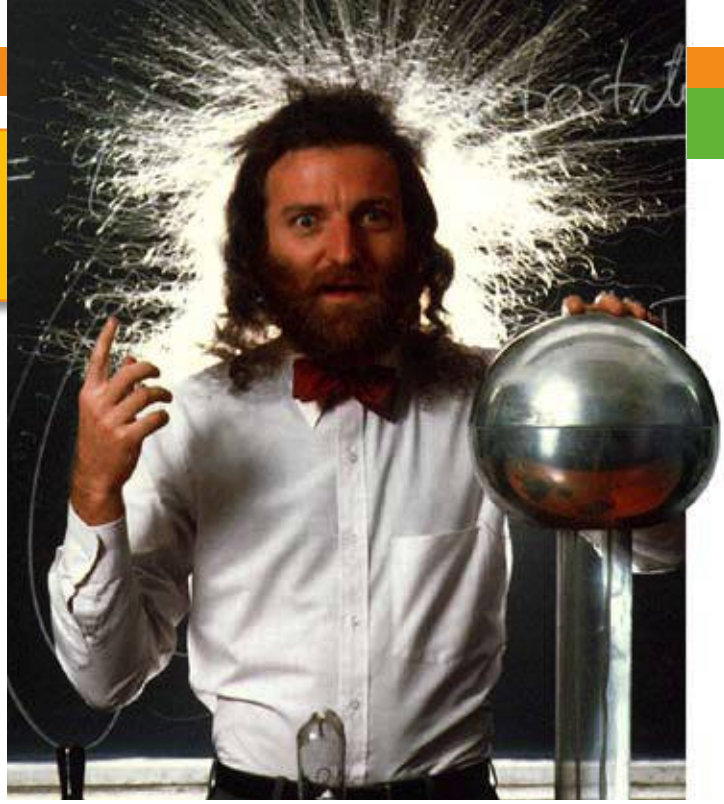
9 P.M. Look through large presentation on the "NBT" discussed this afternoon. Tomorrow is the announcement about the HST planetary discovery — it should be a good day.

Left, clockwise: David Friedlander/NASA; Tsar Fedorsky of Tsar Photo/Harvard University; John Coyle, Jr. for Coyle Commercial Photography/STScI; Melchior DiGiacomo Photography; STScI

GETTING TO KNOW

David **Helfand**

Chair of the Department of Astronomy at Columbia University



*Disclaimer: This photo represents David Helfand as he looked in "ancient history."

Favorite topic to research: I got involved in pulsar astronomy as an undergraduate, and despite my attempts to escape the mesmerizing — and incredibly regular — bursts of radio static these objects emit, I keep returning.

Goals for your field: For radio astronomy, completing the Atacama Large Millimeter/submillimeter Array and the Expanded Very Large Array Project — both goals are in sight — and choosing the right path toward the Square Kilometer Array — not obviously in sight and, because my sight is starting to fail, I have this feeling I may never see it. For X-ray astronomy, taking less than 20 years to decide what the next X-ray observatory should be.

Greatest career moment: I threw a terrific party in Cambridge, England the evening after the announcement that my thesis advisor, Joe Taylor, had won the Nobel Prize. I chose this moment because I have always wanted a career as a chef.

Proudest moment in your life: It's yet to come, I hope. Perhaps it will be when I get to be an official Galileo impersonator for the 2009 International Year of Astronomy.

Favorite thing to do on the weekend: Cooking — mostly classical French and Italian, such as gnocchi alla gorgonzola or coquilles Saint Jacques à la Créole. All of the astronomers and physicists who have eaten my gastronomical undertakings agree that I am a better cook than astronomer — an admittedly ambiguous compliment, but one that I accept nonetheless.

The best thing about living in New York City: I don't have to live other places, all of which are clearly inferior to here, the center of the universe. In addition to the food, the people, the opera, the people, the theater, the people, the museums, the people, and the people, one never has to hear anyone talk about the price of gas because no one owns a car.

Astro**influences** *How did you get interested in astronomy?*

Lisa **Frattare**

Astronomical image processor at the Space Telescope Science Institute in Baltimore

My early memories of astronomy are precious: from reading *Goodnight Moon* to someone pointing to an early evening planet and saying it was "The Star of Bethlehem." I loved staying up late with the shades open at night to watch the Moon and stars traverse my bedroom window.

But one of my most vivid memories of the cosmos was not at night but during the day, with the shade pulled down in my room. Tiny pinprick holes in the shade made up little constellations, and I remember contemplating that perhaps real stars were pinpricks on what would evolve into a celestial sphere shade. Who put them there, and why?

I took astronomy as a college elective and fell in love with it. Stepping out on the roof overlooking Lake Ontario for my first astronomy lab in Oswego, New York, seeing the sunset over the lake and then the crescent Moon and several planets lined up across the sky, I felt I had never seen such a beautiful sight.

"I loved staying up late with the shades open at night to watch the Moon and stars traverse my bedroom window."

To hear more from people featured this month, visit www.Astronomy.com/toc.

NEXT MONTH
in the May issue

Image courtesy of Dr. T.H. Jarrett (IPAC/Caltech)

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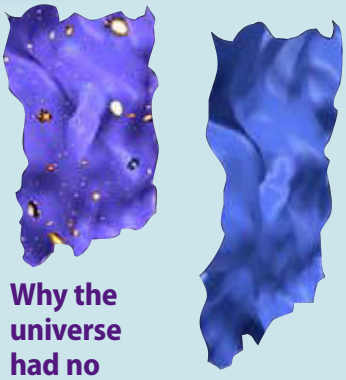

Why the universe had no beginning pg. 28 A+
Watch a video showing how the "branes" collide and separate.

Is the Big Bang in trouble? pg. 48 A+
Learn more about the unsolved mysteries of the standard model.

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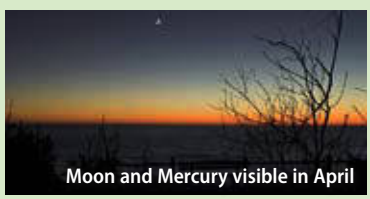
OBSERVING TOOLS


Moon and Mercury visible in April

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Branes collide: Courtesy Paul J. Steinhardt; Moon and Mercury: Mike Salway

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David Christian, professor of Big History at San Diego State University, earned his B.A. and D.Phil. at Oxford University. Nearly 20 years ago, seeking to broaden the pantheon of world history, Dr. Christian pioneered the groundbreaking research and development of Big History—an entirely new academic discipline that is now taught internationally. National Humanities Center Fellow and noted researcher, editor and author, one of his books, *Maps of Time: An Introduction to Big History,* was the winner of the 2005 WHA History Prize for best book in world history.

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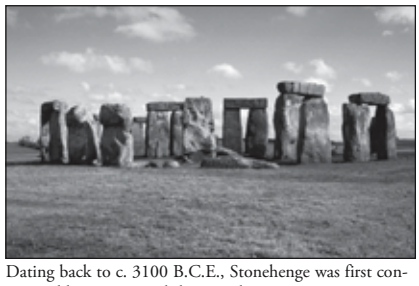

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Dating back to c. 3100 B.C.E., Stonehenge was first constructed by native Neolithic people.

Lecture Titles

1. What Is Big History?
2. Moving across Multiple Scales
3. Simplicity and Complexity
4. Evidence and the Nature of Science
5. Threshold 1—Origins of Big Bang Cosmology
6. How Did Everything Begin?
7. Threshold 2—The First Stars and Galaxies
8. Threshold 3—Making Chemical Elements
9. Threshold 4—The Earth and the Solar System
10. The Early Earth—A Short History
11. Plate Tectonics and the Earth's Geography
12. Threshold 5—Life
13. Darwin and Natural Selection
14. The Evidence for Natural Selection
15. The Origins of Life
16. Life on Earth—Single-celled Organisms
17. Life on Earth—Multi-celled Organisms
18. Hominines
19. Evidence on Hominine Evolution
20. Threshold 6—What Makes Humans Different?
21. *Homo sapiens*—The First Humans
22. Paleolithic Lifeways
23. Change in the Paleolithic Era
24. Threshold 7—Agriculture
25. The Origins of Agriculture
26. The First Agrarian Societies
27. Power and Its Origins
28. Early Power Structures
29. From Villages to Cities
30. Sumer—The First Agrarian Civilization
31. Agrarian Civilizations in Other Regions
32. The World That Agrarian Civilizations Made
33. Long Trends—Expansion and State Power
34. Long Trends—Rates of Innovation
35. Long Trends—Disease and Malthusian Cycles
36. Comparing the World Zones
37. The Americas in the Later Agrarian Era
38. Threshold 8—The Modern Revolution
39. The Medieval Malthusian Cycle, 500–1350
40. The Early Modern Cycle, 1350–1700
41. Breakthrough—The Industrial Revolution
42. Spread of the Industrial Revolution to 1900
43. The 20th Century
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47. The Next Millennium and the Remote Future
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Stellar order

In his news article "Spitzer snaps dusty family portrait" (December 2008), Daniel Pendick mentioned that the oldest stars are located the greatest distance from the center of the cavities. If I understand trigger star formation, shouldn't the oldest stars be closest to the center of the cavities? — **Peter Welch,** Renton, Washington

I made an error in explaining this process. Massive, hot stars lie near the centers of the cavities. Stellar winds from these stars create the cavities by blowing gas outward. As the stellar winds blow outward, they compress the gas at the edge of the cavities and trigger star formation. As the cavities grow larger, new stars continue to form at the edges of the expanding boundary. So I should have said that the youngest stars lie the farthest distance from the center of the cavities. Or, to put it another way, successively younger generations of stars form with increasing distance from the center. — **Daniel Pendick,** Associate Editor

NASA/JPL-Caltech/Harvard-Smithsonian CfA

Star-forming cloud W5 showcases younger stars on the outskirts and older stars toward the center. The Spitzer Space Telescope captured this infrared image.

Observing thin lunar crescents

Many cultures use visual observations of the young lunar crescent to define lunar-based calendars. During the past year friends and I have used a video camera to extend the limits of visual observation.

We observed the lunar crescent near conjunction. Although André Danjon (1890–1967) determined the lunar crescent should vanish entirely when the Moon is closer than about 7° from the Sun, we were able to reach beyond this "Danjon limit" and view the lunar crescent at elongations of less than 5°. Other observers typically made lunar crescent observations during twilight after the Sun moved below the horizon. We instead observed the lunar crescent during the day. This daytime observation is how we were able to reach beyond the "Danjon limit" of classic observations.

Because the Sun's dangerous glare is near the field of view, it's important to use the proper technique. Specially designed baffles in front of the telescope can block direct sunlight and allow safe imaging.

We used a standard black-and-white video camera to image the crescent. To improve the live view, we used special contrast-enhancement options in the capturing software. To block the scattered blue light around the Sun and improve contrast, we used red filters. We mounted the telescope and lengthy baffle system on a sturdy German equatorial mount with go-to capability in order to point the 110-millimeter refractor at the crescent's precise location and follow its motion over several hours. Of course, good clear skies were important, as contrast is the central problem for this imaging.

With these preparations, our imaging technique showed a surprisingly long crescent arc of more than 90° at less than 5° elongation, which is far beyond the supposed Danjon limit. During a whole day of observation around conjunction, the crescent's orientation changed dramatically, as the Moon moved from "old" to "new." The crescent also showed varying brightness where regions of different albedo and different geometry affected the amount of scattered light. — **Martin Elsässer,** Kirchseeon, Germany

Sunrise, two times?

How delighted I was to read Stephen James O'Meara's "The day the Sun crawled" (November 2008). I was relieved to discover that I hadn't been hallucinating that early morning in July 1969 when I watched the Sun rise twice within a few minutes over the plains from my cabin site in the Rocky Mountain foothills of northern Colorado. Apparently the effect is not limited solely to an oceanic horizon. — **Steve Hunter,** Denver

Memories of an aurora

I was excited when I read the answer to a query about a red sky in Chicago before World War II ("Ask Astro," October 2008). I'd been telling my daughter all her life about the aurora in Jersey City, New Jersey, in September 1941.

The skies were blacked out (a precaution during fears of war), and it was at first like searchlights across the sky. Then the white "searchlights" curved, and there were green and red and finally dancing lights. I was a young child, but it stayed with me my whole life.

I've never forgotten the wonder and the beauty. Your answer in "Ask Astro" marked the first time I realized it was anything more than a remarkable sky in Jersey City — that a good part of the country shared my experience. It created in me a lifelong fascination with astronomy. — **Jewel Seehaus-Fisher,** Highland Park, New Jersey

Correction

In the December issue, on page 68, the middle-left image shows the double quasar Q 0957+561 A+B in Ursa Major, not PKS 1354+19 in Boötes. — ***Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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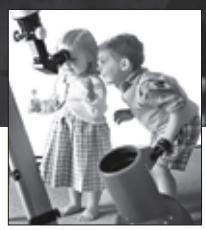

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Strange Universe

by Bob Berman

Major mess-ups . . . maybe

So-called setbacks in astronomy can lead to even greater achievements.

A famous fable tells of a wise farmer. When his only horse ran away, the neighbors groaned, "What bad luck!" But the farmer just said, "Maybe."

The next day the horse came back leading 10 wild horses. The farmer was rich! The neighbors said, "You're so lucky!" But the farmer said, "Maybe."

That afternoon his son was thrown while trying to train one of the new horses and broke his leg. The neighbors said, "How terrible!" But the farmer shrugged, "Maybe."

The next day men from the army came to draft the boy for the war but, seeing the broken leg, left without taking him. The neighbors cheered, "What good fortune!" The farmer said, "Maybe."

Historically, space science has been like that. Famous astro-busts may have been blessings in disguise.

In 1971, President Nixon canceled the final three Apollo missions. The Saturn rockets had been built, the astronauts trained, and now suddenly they'd never fly to the Moon. Nixon hated Apollo anyway — his old nemesis John Kennedy was still getting posthumous praise for creating the project. Nixon was happy to see it vanish even if many were disappointed. But he was probably right. Each mission was super-dangerous, as Apollo 13 underscored. And Apollo 17 just missed getting a lethal blast of solar particles. With a dozen men already having walked on the Moon, why keep going until someone got killed? If any of the final astronauts died in space, a pall would forever fall on the whole accomplishment. It wasn't such a bad idea to quit while we were ahead.

Or take the Hubble fiasco. The long-awaited billion-dollar space telescope was launched with a misshapen funhouse mirror, thanks to faulty testing. Its view resembled what you'd see through those plastic binoculars you win at a carnival. Astronomers went from denial to anger on the Kubler-Ross scale of grief. The situation seemed hopeless. But as it turned out, 1993's creative fix-it mission starring the strange genius and NASA astronaut Story Musgrave was space science's finest hour. More than a total success, it demonstrated the shuttle's unique abilities and aimed a bright global spotlight on the American can-do spirit.

Fast-forward to 2009: After two tragedies and the loss of nearly half the shuttle fleet, the remaining ships will be canceled like a commuter train. Scrapped. Soon we'll have no way to send people into space — for years. We'll have to bum rides with the Russians. Our nation, reduced to hitchhiking? Is this as bad as it sounds?

Famous astro-busts may have been blessings in disguise.

Maybe not. The pause will save money and give us time to weigh the lessons we have learned. The shuttles enlightened us to the hazards of manned spaceflight — and their super-high costs — like nothing else. Result: better designs and the knowledge that even lavish sums of taxpayer play-dollars can't make space truly safe. Like all adventures, it's perilous. Public policy will no longer pretend to send schoolteachers up with little risk.

And how should we feel about these ever-increasing delays to Mars? During the Apollo years, experts were sure we'd walk on martian soil by 1982. In the 1980s, the date had become 2000. Now projections say 2035. Discouraging? This go-slow reality actually might be a good thing. Mars is the only planet of possible residence, making it a unique goal. While assertiveness is natural to some human activities, like barroom brawling or marrying on impulse, caution may be wiser with something as precious as our dreams of other worlds. If the first visitors died on Mars, so would our visions of starry pastures. Launching only when we're truly prepared might serve us better than a tentative colonization attempt that ends in a depressing accident or radiation-induced debilitation.

Failed mega-projects provide chances for reflection, too. When Congress canceled the $50 billion super-collider in Texas in 1993, our nation surrendered the cutting edge of subatomic physics to the European CERN consortium. Academicians groaned. But was this really so bad? Most of us already are bored with today's mind-numbing list of particles. The Large Hadron Collider will surely discover many more bits of evanescent flotsam. To what end? Bosons, mesons, pions, kaons, anti-quarks, J-particles — how much of this can we handle? Desperate theorists keep hoping for the Higgs Boson and other ultimate answers. A Grand Unified Theory of Everything. Yeah, right. Any day now.

Navigating the particle swamp will keep Europeans occupied for decades, a vast improvement over their traditional warfare pastime of bygone centuries.

But what about the unnamed blue star that exploded in this neighborhood 5 billion years ago? If you knew it was coming, you'd have said, "How awful!" But material from that supernova ultimately created our world.

So when the next Big Thing gets canceled or messed up and everyone says, "Isn't that terrible?" I'll try to remember the farmer: "Maybe."

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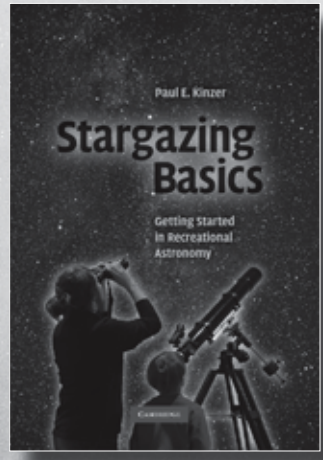

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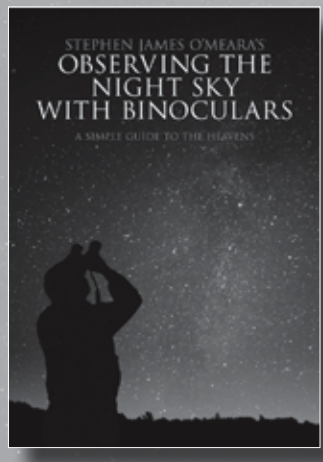

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Secret Sky

by Stephen James O'Meara

Searching for shadow bands

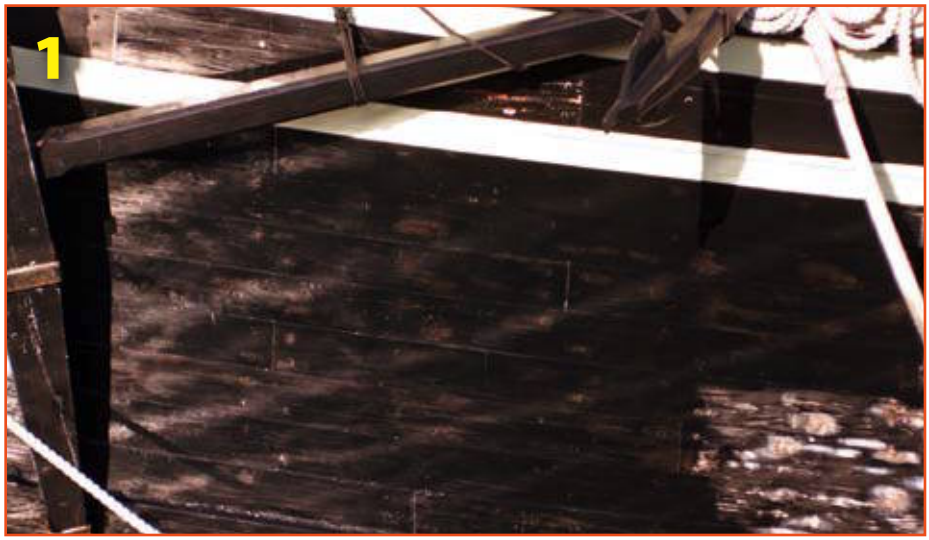
This eclipse phenomenon can surface more often than you'd expect.

In my March 2009 column, when I told you about the wonder of seeing shadow bands without an eclipse, I had no idea that searching for these phantom serpents of the air (which slither in long dark waves and patches across bright surfaces) would become so habit forming. I was going to let the subject slide for a few months, but my enthusiasm to share with you some more observations overtook me.

The non-eclipse shadow bands I described last month occurred when a flat horizon had partially eclipsed the Sun during its rising or setting. But can you see shadow bands when the Sun is higher in the sky?

One day last September, I was at home on our deck reading a book. The Sun was high in the south and partially eclipsed by a roof, whose shadow fell onto one of the book's pages. Curious, I opened the book flat to some blank pages and placed it so the roof's shadow hit it lengthwise and paralleled the bottom of the pages. Then I waited to see what would happen.

To my surprise, I saw shadow bands, about half an inch apart, rippling diagonally across the pages. The air was generally still, with some occasional breezes. Whenever the breezes blew, the bands broke up into a chaotic brew of swirling vapors. These bands, I realized, were from a local atmospheric disturbance: heat rising from the house's hot tin roof!



Shadow bands are a series of alternating light and dark parallel lines, several feet in length, that seem to ripple across the landscape like moving water waves. In fact, they look and behave like light reflections from the rippled surface of water. As shown in this pair of images, when the water is calm, the light reflections appear as long, parallel waves (1). Blowing wind, however, can disturb this placid pattern, making it appear more chaotic (2). Stephen J. O'Meara

"Seeing" effects

Turbulent air, whether it's local (such as heat rising from hot pavement) or distant (a high-altitude jet stream), can impair the view through our telescopes, causing images to blur, blister, or boil.

The open-ended tubes of classical Newtonian reflectors are also affected by internal tube currents — rushes of warm air rising from the mirror through colder layers in the tube. The ever-moving boundaries between the interacting layers act like weak lenses that deflect incoming rays of light in a most erratic fashion; that's why it's important to let a telescope's mirror "cool down" to the outside temperature before beginning any critical viewing session.

If you want to see how turbulent air plays with the telescopic image of a

bright star in detail, just rack the star well out of focus until it's a large, even disk of light. Now wait and watch. The "seeing" effects described above will reveal themselves as shadow bands playing on (and dancing across) the bright disk. John E. Willis called them "stellar shadow pictures" in 1925.

In my experience, fast, high-altitude seeing effects produce long rushing streams of parallel light that make the image appear as if you're watching it under running tap water. Slow seeing effects — those commonly associated with tube currents and local ground-seeing — generally appear as smoky curls and dappled shadows that sway and twirl slowly across the disk.

Heat from your body can also interfere with the air around you and your telescope. And you can see the effects, as Phil McAfee of Johnson City, Tennessee, learned during a partial solar eclipse, presumably January 24, 1925. As reported in a 1936 issue of *Popular Astronomy*, McAfee saw against a clean white sheet, "the plainly visible shadows of the heat waves rising from my own body, even from the tip of my finger … and hand."

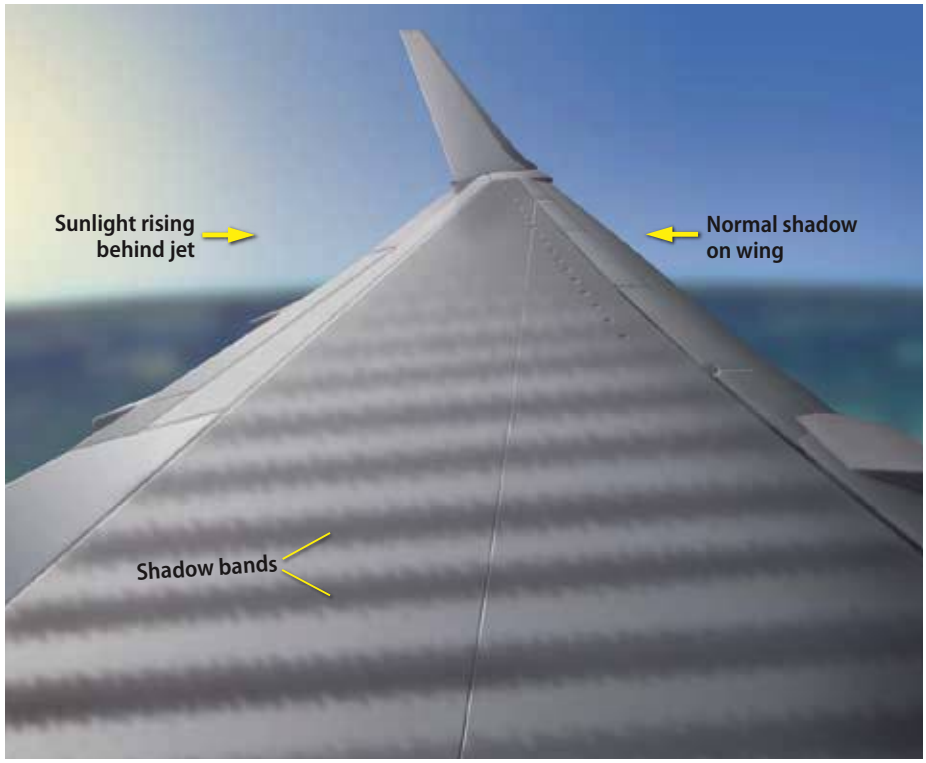
You too can see heat waves rising from your own body (particularly your head!) anytime when the air is still and the Sun is partially eclipsed, especially by a flat, distant horizon during the times of sunrise or sunset.

Moon shadow

If non-eclipse shadow bands are visible during the day, what about at night, especially during a Full Moon?

Although I have not seen a Full Moon rising or setting behind a flat horizon without clouds since my search for shadow bands began, I did see these serpents of the air at night in October 2008 when the First Quarter Moon was hanging low in the sky. (After all, what is a half Moon on its side but a half-eclipsed Full Moon!)

The moonlight, which was shining through the open vertical slats lining the outside of our garage, fell onto the white surface of our Toyota Echo. There, between the shadows of the slats, I saw shadow bands rising up in waves parallel to the Moon's terminator. Again, the air was extremely still. I tried to repeat this observation on following nights when the Moon was filling in and the wind was blowing, but I saw nothing.



On February 1, 2006, the author observed high-altitude shadow bands on the wing of a jet as the Sun was rising behind the aircraft. This illustration demonstrates how the band vibrated rapidly in place when he focused his attention on a single band with direct vision. When he averted his vision, the shadow bands appeared to move rapidly outward on the wing. *Astronomy*: Roen Kelly

High-flying shadows

Observations of shadow bands are not confined to Earth's lower atmosphere. As A. Lawrence Rotch describes in the 1908 *Annals of the Astronomical Observatory of Harvard College*, a group made the first attempt to see shadow bands at higher altitudes during the August 30, 1905, total solar eclipse.

At Rotch's request, white screens were hung horizontally below balloons piloted by a corps of military observers in Burgos, Spain. The observers saw shadow bands clearly from at least one balloon at 12,500 feet (4 kilometers). The bands measured about 2 inches (5 centimeters) across, were separated by 3 to 4 inches (8cm to 10cm) — much finer than those detected on the ground — and moved at about 5 feet (1.5 meters) per second.

Can non-eclipse shadow bands also occur high in the air?

On February 1, 2006, I was on a jet that departed Hilo, Hawaii, about 15 minutes before sunrise. As the jet climbed to an altitude of about 14,000 feet (4 km), I saw orange light from the Sun (which was rising directly behind the jet) fringe the forward part of the jet's silver wing. Suddenly, a dramatic and obvious display of shadow bands covered the jet's wing.

The bands were perpendicular to the length of the wing and formed thick dark stripes, about 3 or 4 feet (0.9 to 1.2m) across, interspersed with equally wide bright bands. When I focused my attention on a single dark band with direct vision, I saw the band flicker or vibrate rapidly in place; otherwise it did not move. When I used averted vision, all the dark bands seemed to move away from the window toward the wingtip at about 4 feet (1.2m) per second.

Repeating any of my shadow band observations, or searching for new ways to see these phantom serpents of the air, requires only a few minutes. But the reward is worth it. If you're a teacher, you might want to create experiments with heated air in the classroom to create these curious displays and get kids interested in the playful wonders of the open air. And then send your reports to me at someara@interpac.net.

Spaceport go for launch New Mexico officials announced December 18 that the Federal Aviation Administration has greenlighted the state's plan to build a commercial spaceport.

For the latest news on space discoveries, spacecraft missions, and sky events, visit **Astronomy.com/news**

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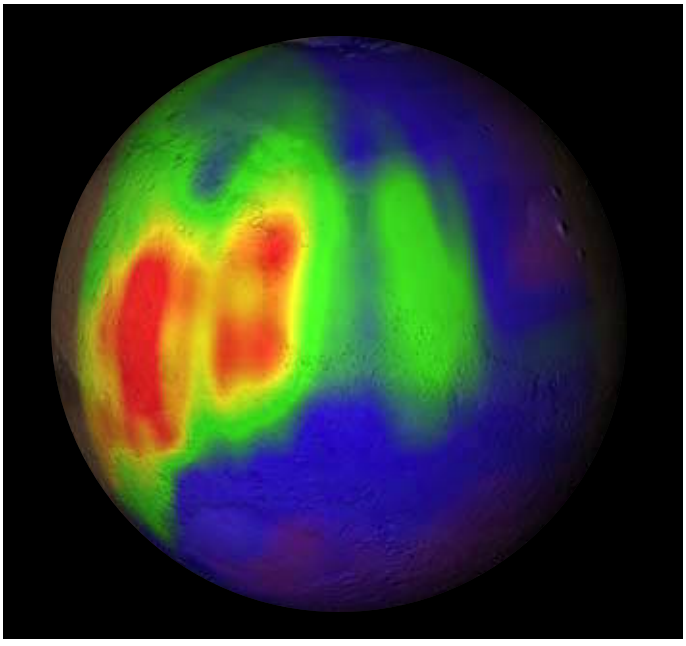


Gas planet. In this false-color image, red indicates the highest concentration of methane spotted on Mars by Earth-based telescopes. Scientists don't know what process generates the gas. NASA

Methane reveals Red Planet's active innards

Some as-yet-unknown process is pumping substantial amounts of methane into the martian atmosphere, scientists announced January 15. Researchers made the discovery by observing the planet over several Mars years with NASA's Infrared Telescope Facility and the Keck Telescope, both at Mauna Kea, Hawaii, and the Gemini South Telescope in Chile.

The telescopes documented methane plumes that appeared sporadically and increased in the summer. Individual plumes contained as much as 21,000 tons of the gas. The discovery feeds hope that microbial life on Mars may be generating the gas, just as on Earth. On the other hand, a purely geological process — like water interacting with molten rock inside volcanoes — could also produce the methane.

Either way, the finding shows that Mars is geologically or biologically active, a sharp contrast to the popular image of the Red Planet as a cold, dry, dead remnant of a formerly watery and environmentally dynamic world. — **DANIEL PENDICK**

22 Chandra peers deep into the Tarantula's lair

23 Discovery boosts Milky Way spin and mass

24 Dimmest brown dwarfs found

25 Extrasolar planet tightens its waistline

26 Milky Way's central black hole gets weighed

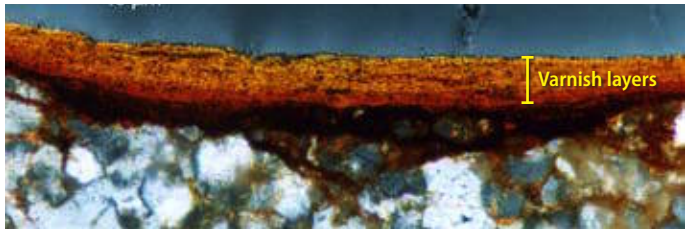
26 Titan's bright spots point to eruptions

Rock coatings could harbor martian microbes

The search for signs of microscopic life on Mars should include thin rock coatings called varnishes, researchers reported December 3 in the *Journal of Geophysical Research-Biogeosciences*.

The varnishes form on rocks in dry climates. The study suggests such coatings could shelter microbes from the cold, dry martian environment.

Terrestrial varnishes consist of clay particles glued together by dark chemical compounds similar to rust. The varnishes grow layer by layer up to 500 micrometers (about 1/50 inch) thick but are typically much thinner.



Martian refuge? This cross-section of a rock sample from Chile's arid Atacama Desert reveals a thin dark coating, or varnish, that shelters a variety of microbes. Courtesy Kimberly R. Kuhlman (PSI)

Researchers led by Kimberly R. Kuhlman of the Planetary Science Institute in Tucson, Arizona, sampled rock varnishes in the arid Atacama Desert near Yungay, Chile, for signs of microbial life.

The coatings contained some 32 different species of bacteria. In comparison, the surrounding soil is virtually devoid of life.

If varnishes exist on Mars, they could provide protection from the parched climate, infrared radiation, and toxic chemical reactions that probably sterilize the top layer of the soil. Also, Kuhlman says, varnish might harvest moisture from passing fog. — **D. P.**

X-ray: NASA/CXC/SAO/A. Vikhlinin et al.; Optical: SDSS

Galactic glow. **To confirm dark energy, scientists observed galaxy clusters like Abell 85, shown here swathed in X-ray emitting gas.**

New evidence backs dark energy

A new test has independently confirmed the existence of dark energy, scientists reported February 10 in *The Astrophysical Journal*. Researchers used the Chandra X-ray Observatory to determine how galaxy clusters have evolved over cosmic time under dark energy's influence.

Scientists discovered in 1998 that something is making the universe expand at a faster rate. They called this something "dark energy." It makes up 72 percent of the universe, but nobody knows what it is.

Astronomers discovered dark energy by measuring how cosmic expansion increases with distance. The latest test looked for dark energy's effects on the growth of galaxy clusters. Over time, dark energy's repulsive effect should put the brakes on the growth of such clusters by counteracting gravity's pull.

Astronomers observed 86 galaxy clusters at varying distances: roughly half are about 5 billion light-years away, while the rest lie less than half a billion light-years. The scientists measured both the masses of those clusters and the number of clusters at the varying distances.

"The growth of structure has slowed down in the past 5 billion years," says Alexey Vikhlinin of the Smithsonian Astrophysical Observatory. "This is an unmistakable signature of dark energy." Scientists believe that around 5 billion years ago dark energy "kicked in."

Both tests give consistent results, so astronomers can combine them to potentially probe the underlying properties of dark energy. — **LIZ KRUESI**

Weathering heights. **Stair-step patterns in the eroded Becquerel Crater may represent a record of cyclical climate change on Mars.** NASA/JPL-Caltech/University of Arizona

Rocky strata reveal climate change on Mars

Rhythmic patterns in rock layers on Mars represent an extended record of climate change on the planet, researchers reported December 5 in *Science*. Kevin Lewis of Caltech in Pasadena, California, and his colleagues used Mars Reconnaissance Orbiter (MRO) images to document climate-related patterns in sedimentary rock formations at four locations in Arabia Terra, a region north of the martian equator.

The rock formations occur in large impact craters. During past climatic epochs, sediment settled into the craters and hardened. Wind erosion later exposed previously buried layers, creating a stair-step pattern on the craters' slopes.

The steps formed as the wind ate into alternating layers of harder and softer rock. In one of the craters, called Becquerel, the steps occur in bundles of 10 that form larger-scale steps on the crater slopes.

Researchers think the stepped pattern records periodic changes in the tilt of Mars' axis, which vary in a cycle lasting about 120,000 years. The smallest steps formed during these intervals. Every 10 to 20 cycles, the degree of tilt becomes especially pronounced. This could explain the 10-step bundling pattern MRO imaged.

The MRO survey represents the first time scientists have tied geological features on Mars directly to swings in the planet's tilt that presumably helped drive climate change. Climate-related changes in environmental conditions may explain the swing between harder and softer sediment layers. — **D. P.**

QUICK TAKES

ALMA GETS FIRST DISH
The first of 66 antennas for the Atacama Large Millimeter/submillimeter Array (ALMA), being built by an international consortium, arrived December 18 in the Chilean desert.

KNIGHT FLIGHT
WhiteKnightTwo, the jet plane that will launch Virgin Galactic's tourist spaceship, made its maiden flight from California's Mojave Air and Space Port December 21.

PRIVATE DELIVERY
Private companies Orbital Sciences Corp. and Space Exploration Technologies will help service the space station starting in 2010, NASA announced December 23.

ROVERS MARK 5 YEARS
NASA's Spirit rover marked 5 years on Mars January 3. Its twin, Opportunity, notched the same anniversary January 25.

RUSSIA'S GPS IS NEAR
Russia launched three more satellites December 25 for its global navigation array, GLONASS. Four more birds will complete the 24-satellite system.

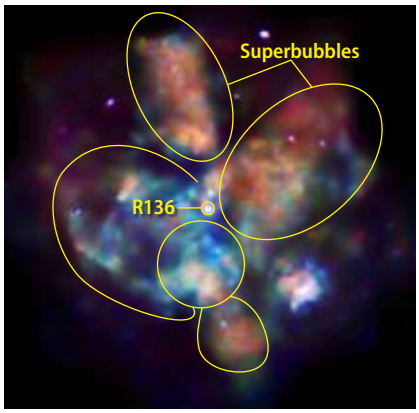
A STARRY YEAR BEGINS
VIPs attended the official opening ceremony for the International Year of Astronomy 2009 at a ceremony in Paris January 15 and 16.

FAHRENHOT
On December 12, researchers reported discovering one of the hottest stars ever seen. The sun's searing surface temperature reaches 360,000° Fahrenheit (200,000° Celsius).

VIETNAM'S NEW SKY EYE
The Vietnam News Agency reported December 13 that the country would launch its first satellite by 2012 dedicated to weather, environmental, and natural resource studies.

6 UP, 8 TO COME
French launch company Arianespace SA launched its sixth and final Ariane 5 rocket of 2008 December 20 with two communications satellites. Up to 8 launches are planned in 2009.

WAY-OUT WATER
On December 17, astronomers reported discovery of the most distant water ever observed in a galaxy far, far away — 11 billion light-years from Earth.



NASA/CXC/Penn State (L. Townsley)

Extreme exposure. The Chandra X-ray Observatory focused on the Tarantula Nebula for 31 hours to capture this deep portrait. It highlights vast "superbubbles" blown in the nebula by exploding stars.

Chandra peers deep into the Tarantula's lair

Astronomers got the most detailed X-ray portrait to date of the Tarantula Nebula, located about 163,000 light-years from Earth in the Large Magellanic Cloud. The new image, captured by the Chandra X-ray Observatory, provides a more detailed look at star birth in the nebula.

To create the image, Chandra focused on the gas cloud for nearly 31 hours. "It's as if we had been looking at the Tarantula Nebula with poor vision, and now we have put on our glasses and we can see the fine details," says Leisa Townsley, an astronomer at Pennsylvania State University who has studied the vast star-forming region for nearly a decade.

A cluster of stars, called R136, lies at the Tarantula's heart. It contains at least 200 massive young stars. Their intense radiation and fierce outflowing winds of charged particles compress and heat gas, igniting new stars. Arrayed around the cluster are several "superbubbles" carved into the nebular gas by exploding stars.

The Tarantula Nebula and other massive star-forming regions provide a microcosm of the processes that drive the birth of successive generations of stars in galaxies.

Heat and pressure from massive stars play a decisive role. "It can trigger new stars by plowing up material and compressing it," Townsley says, "but it also halts the formation of stars and planets by clearing out gas and dust." — **D. P.**

Muscle car. NASA's plutonium-powered Mars Science Laboratory, shown in this artist's concept, is bigger, faster, and freer than any previous rover. Its main body is about 10 feet (3 meters) long. NASA/JPL-Caltech

Roving Mars lab delayed for 2 years

NASA announced disappointing news at a December 4 press briefing: The hotly anticipated Mars Science Laboratory (MSL) mission will launch in 2011, 2 years later than previously planned. MSL is a six-wheel, nuclear-powered buggy the size of a small car. It's designed to assess the Red Planet's habitability — whether it ever was, or is still today, able to support microbial life.

MSL fell prey to unresolved technical glitches in the dozens of electric motors, called actuators, that turn the robot's wheels, flex its arm, and manipulate soil samples. A single company — Aeroflex Inc. in Plainview, New York — makes the actuators for NASA.

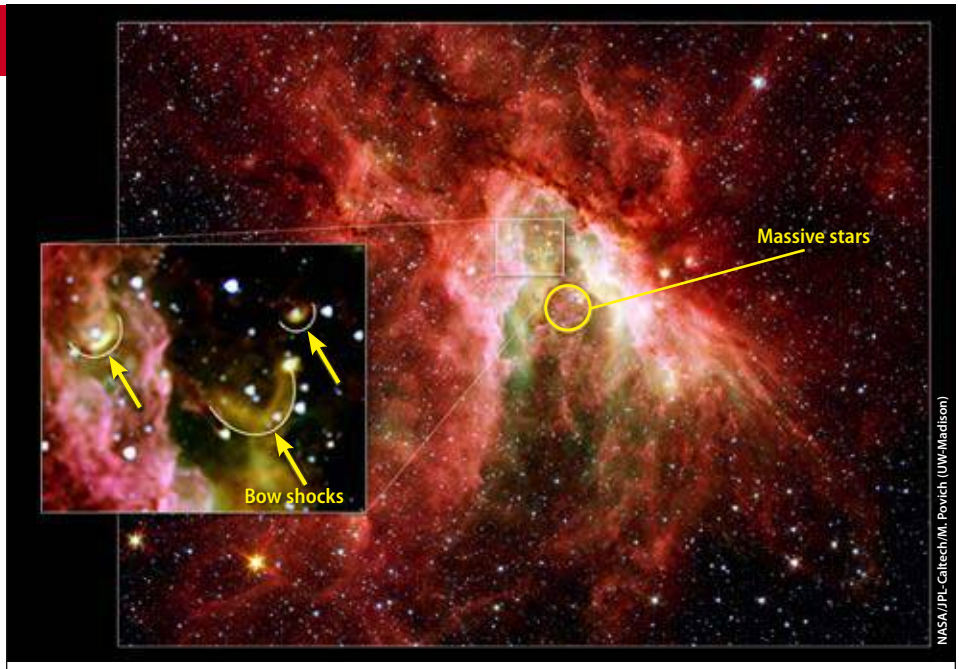
Engineers might have been able to fix the problems in a matter of months, but that would have still been too late to meet the fixed launch window for sending the spacecraft to Mars. The alignment of Earth and Mars is ideal only once in every 26 months. The delay may cost up to $400 million. That money will have to be diverted from other NASA efforts and is likely to delay at least one upcoming major planetary mission.

If MSL does launch in 2011 as planned, planetary scientists can look forward to an unprecedented tour of the Red Planet. A key feature of the rover is its radioisotope power system, which generates electricity from plutonium's radioactive decay. This power plant gives the mission an operating lifespan on Mars' surface of a full martian year (687 Earth days) or more.

Unfettered by the solar panels that trickle power to the Mars Exploration Rovers Spirit and Opportunity, MSL will be a veritable superhero of martian robots. It'll be able to roam farther and faster than any mission to date. Despite its 1,984-pound (900 kilograms) heft, the rover should be able to traverse the terrain at an average of 98 feet (30 meters) per hour. Its range will vary depending on local conditions like slippage, steepness of the terrain, and visibility.

A variety of scientific activities are planned using instruments provided by the United States, Canada, Germany, France, Russia, and Spain. MSL will taste the soil for chemical ingredients of earthlike life, look for signs of biological processes, and assess climate and environmental conditions. MSL's instruments will also conduct basic studies of Mars' surface geology and geochemistry.

Mission planners hope MSL will build on the wealth of data acquired by the successful Mars Exploration Rovers and Phoenix Lander. But it may be the last flagship mission to Mars to sport a single flag on its robots. The total cost of MSL could hit $2.3 billion. The ballooning price tag of planetary exploration has NASA administrators talking publicly about teaming up with the European Space Agency in future robotic missions. — **D. P.**



Blast waves. Researchers found turbulent "bow shocks" around three stars in the Omega Nebula (M17). A cluster of massive suns drives gas against other stars, creating the shocks.

Spitzer images the Omega Nebula's stormy seas

A new image from the Spitzer Space Telescope highlights the turbulent conditions in one of the most extreme star-birth regions in the Milky Way, the Omega Nebula (M17). Rivers of gas collide with outflows from young stars, raising turbulent "bow shocks" like those that form around the bow of a speeding ship. Matthew Povich of the University of Wisconsin-Madison and his colleagues described newly discovered features of M17 December 10 in *The Astrophysical Journal*.

The nebula hosts a central cluster of about 20 massive stars that blow off dense outflows of charged particles. These stellar winds have carved a deep cavity in M17's heart, driving rivers of nebular gas toward other stars. As gas interacts with the winds of the outlying stars, bow shocks form.

Astronomers have observed bow shocks before, Povich says, but usually in front of stars moving at high velocities through thin interstellar material. In the new Spitzer image, the bow shocks form around stars still in their birth regions. The shocks develop as gas flows around the stars, like water flowing past a stone in a streambed.

M17 is a boiler room of star formation, Povich says. "Bow shocks have not been observed before in such extreme environments." The bow shocks help gauge the flow of energy in the nebula and better understand what triggers star birth. — **D. P.**

Discovery boosts Milky Way spin and mass

The Milky Way Galaxy rotates significantly faster than previously thought, astronomers announced January 6 at a meeting of the American Astronomical Society in Long Beach, California. The higher speed means our galaxy is also 50 percent more massive — about the same as that of the neighboring Andromeda Galaxy.

Researchers led by Mark Reid of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, used the Very Long Baseline Array radio telescopes to measure the precise distances to multiple star-forming regions in the Milky Way. Knowing these galactic reference points enabled the astronomers to calculate the Milky Way's rotation speed and mass.

At the Sun's distance from the galactic center, the Milky Way rotates at 568,200 mph (914,400 km/h). This estimate is about 15 percent faster than the previous speed. Incorporating both normal and dark matter, the Milky Way weighs in at some 3 trillion times the Sun's mass. — **L. K.**

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Double duty NASA and the European Space Agency agreed December 3 to consider future partnerships to launch robotic Mars missions. It would include sharing costs.

BRIEFCASE

Beagle2 probe may have spun too fast

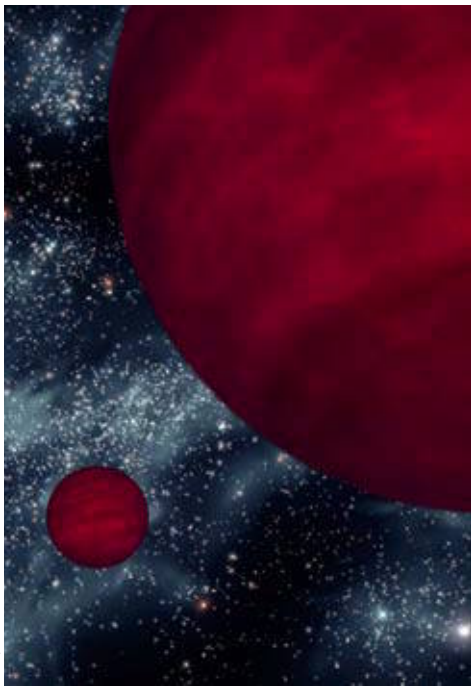
A faulty calculation may have doomed the British Beagle2 lander as it entered Mars' atmosphere Christmas Day 2003. Scientists from Australia's University of Queensland reported the finding in the November-December issue of the *Journal of Spacecraft and Rockets*. Calculations suggest the craft, still in its protective aeroshell, was spinning too fast as it hit the martian atmosphere, tumbled, and burned up. — **D. P.**

PanSTARRS 1 comes on line

On December 22, the University of Hawaii declared the first of four telescopes in its Panoramic Survey Telescope and Rapid Response System (PanSTARRS) ready to do science. The four-barreled instrument, slated for completion by 2012, will attempt to pinpoint the estimated 100,000 near-Earth asteroids measuring between 460 feet (140 meters) and 3,280 feet (1 kilometer) across. — **D. P.**

China to build giant dish

China broke ground December 26 for what will be the largest single-dish radio telescope in the world. The country's National Astronomical Observatories expect to begin operating the 1,640-foot-wide (500 meters) instrument by 2014. The Five-hundred-meter Aperture Spherical Telescope (FAST) is under construction in a natural depression in Guizhou Province. The 1,000-foot-wide (305m) Arecibo radio telescope in Puerto Rico holds the current size record. — **D. P.**



NASA/JPL-Caltech

Not so bright. Astronomers found the dimmest brown dwarfs known. Each of the objects is only one-millionth as bright as our Sun.

Dimmest brown dwarfs found

Astronomers have found what are likely the two dimmest brown dwarfs ever seen. These faint objects are balls of gas that produce light, but not by nuclear fusion.

The newly discovered dwarfs are probably twins that each glow one million times weaker than our Sun. The astronomers' findings appeared December 10 in *The Astrophysical Journal Letters*.

Scientists used the Spitzer Space Telescope to detect the dim pair's combined heat output. Originally, astronomers thought the glow came from a single body with a temperature between 560° and 680° Fahrenheit (292° and 360° Celsius).

The single brown dwarf, however, was too luminous for an object of that temperature. Therefore astronomers believe the object isn't one brown dwarf, but two of roughly equal size.

The twin brown dwarfs are some 30 to 40 times more massive than Jupiter. Such objects are the coldest, least massive, and faintest starlike celestial bodies. However, they are still larger and brighter than planets. — **L. K.**

25 years ago in *Astronomy*

April 1984

In the April 1984 issue, astronomer Laurence A. Marschall introduced readers to superclusters. As Marschall explained in "Superclusters: giants of the cosmos," such gargantuan galactic groups have much to teach scientists about the underlying structure of our seemingly limitless universe.

Much work remained to be done. "The search for a complete understanding of the structural framework of our universe is just beginning," Marschall wrote. "We have mapped only a short pace outward toward the limits of our universe."

Galaxies gather in clusters. The clusters form much larger conglomerations called superclusters. These enormous structures stretch across hundreds of millions of light-years. They are among the largest objects in our universe. Superclusters showed that galaxies are not distributed uniformly in space. — **MEGAN McCHAIN**

April 1999

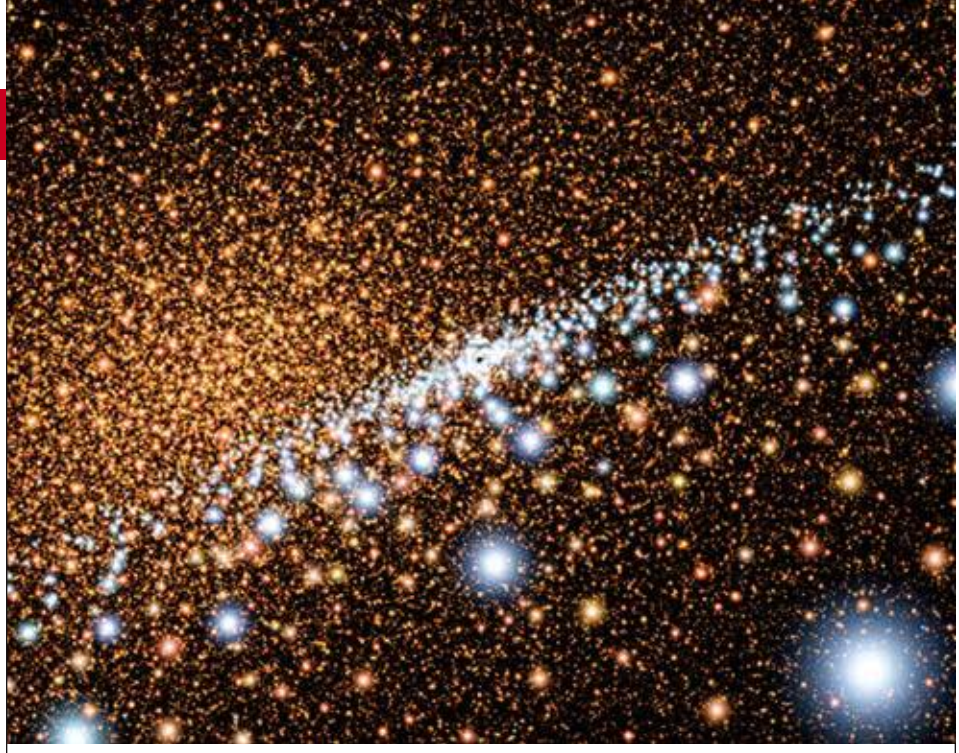
10 years ago in *Astronomy*

In the April 1999 issue of *Astronomy*, William K. Hartmann's "Invading martian territory" reported findings from NASA's Mars Global Surveyor (MGS) mission. Launched in November 1996, the craft went into orbit around the Red Planet in September 1997. Scientists tapped the craft's powerful 14-inch telescopic camera and other instruments to probe the surface geology of Mars.

Key scientific questions MGS investigated included the history of flowing water and volcanic activity. After 18 months in orbit, the orbiter had revealed new clues that Mars was more geologically active — and for a longer time — than scientists had thought.

MGS images of dry riverbed channels deepened understanding of the history of running water on Mars. The new evidence suggested that the Red Planet's watery past extended beyond a single early episode — that it might have experienced alternating wet and dry periods.

MGS continued to explore Mars until November 2, 2006, when it failed to respond to commands from Earth. NASA officially ended the long and successful mission in January 2007. — **D. P.**



Star search. **In this artist's concept, young blue stars share the Milky Way Galaxy's core with older red ones. Astronomers caught two stars forming within a few light-years of the galaxy's giant central black hole.** NASA/ESA/A. Schaller (for STScI)

Stars form in Milky Way's hostile heart

Astronomers confirmed that stars can form near the supermassive black hole at the Milky Way's center despite the disruptive forces at work. Researchers led by Elizabeth Humphreys of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, reported their findings January 6 at a meeting of the American Astronomical Society in Long Beach, California.

Previous research identified young stars relatively near the central black hole. How they got there is a long-standing mystery. Tidal forces from the black hole should, theoretically, rip anything apart.

Humphreys and colleagues used the Very Large Array of radio telescopes in Socorro, New Mexico, to look for a special type of radio signal that indicates the presence of infant suns still embedded in their birth cocoons of gas and dust.

The astronomers found clear signs of protostars 7 and 10 light-years from the galactic center. In addition, gas orbiting the black hole is some 10 to 1,000 times denser than previously thought. This might allow the clouds to remain intact and collapse to form stars despite their relatively close proximity to a giant black hole. — **L. K.**

Extrasolar planet tightens its waistline

The extrasolar planet astronomers thought was one of the most bloated ever found is actually one of the most compact. A team of astronomers led by John Johnson of the University of Hawaii's Institute for Astronomy made the discovery using a supersensitive digital camera and the university's 2.2-meter telescope on Mauna Kea.

The planet, WASP-10b, orbits a star 290 light-years from Earth. When astronomers first discovered the gas-giant planet in June 2008, they estimated its diameter at about 28 percent larger than Jupiter.

Johnson's team used a new and more sensitive type of instrument, the Orthogonal Parallel Transfer Imaging Camera (OPTIC), to measure the minuscule dip in light from the parent star, WASP-10, as the planet passed in front of it. The size of the dip indicates the diameter of the planet: The bigger the planet, the bigger the dip.

The new data revealed that the planet is only 8 percent larger than Jupiter although it packs 3.3 times the mass.

OPTIC is sensitive enough to detect the passage of a moth in front of a lit window from a distance of 1,000 miles (1,600 kilometers). Instruments slightly more sensitive than OPTIC could measure the diameters of Earth-sized extrasolar planets. — **D. P.**

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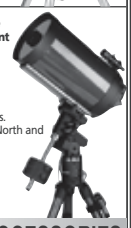

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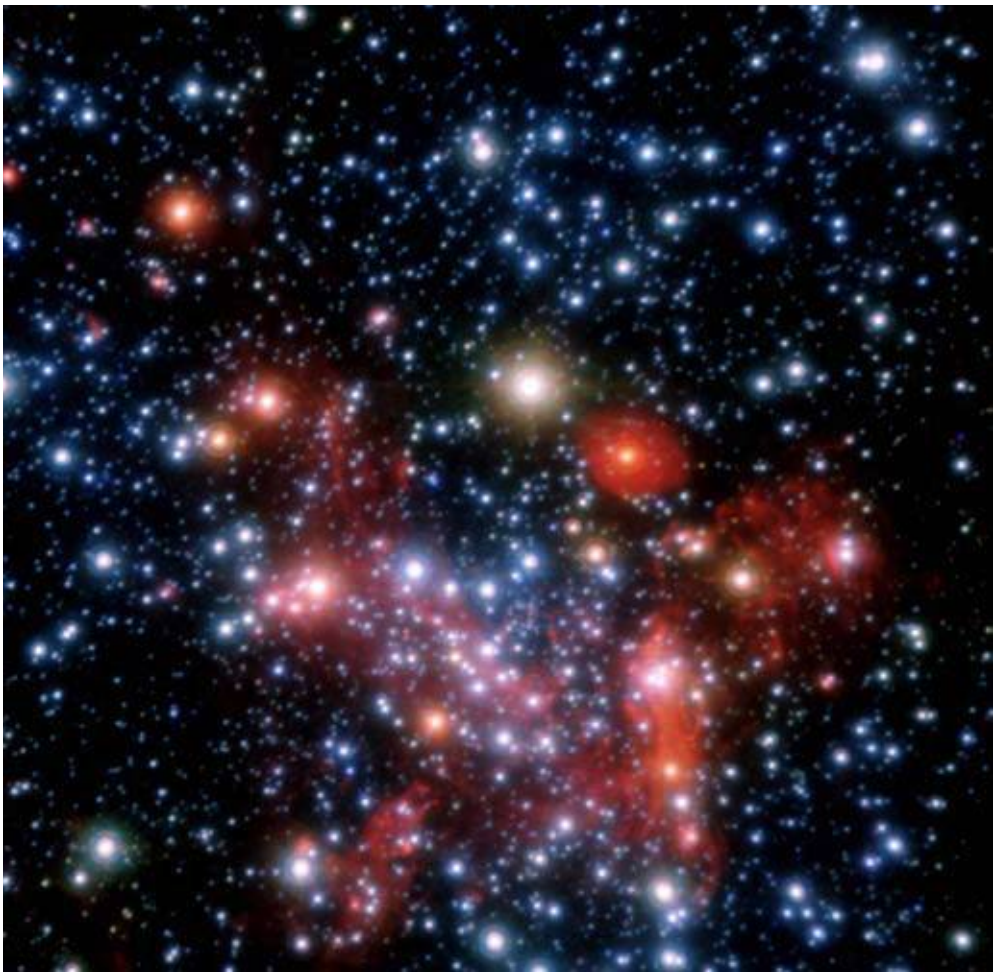
Are we there yet? NASA's MESSENGER probe to Mercury passed 3 billion travel miles December 26, more than 60 percent of the distance to final orbit March 18, 2011.



Black hole home. The European Southern Observatory's Very Large Telescope captured this image of the Milky Way's central region in near-infrared. A supermassive black hole lurks in this core region. ESO (S. Gillessen et al.)

Milky Way's central black hole gets weighed

Astronomers tapped 16 years of observations of the Milky Way's center to produce the most accurate description yet of the supermassive black hole lurking at our galaxy's core. The black hole, called Sagittarius A* (pronounced "A-star"), contains 4.31 million times the Sun's mass and lies about 27,200 light-years from Earth.

A team led by Reinhard Genzel of the Max-Planck-Institute for Extraterrestrial Physics in Garching, Germany, reported the new estimates December 20 in *The Astrophysical Journal*.

Genzel's team estimated the mass of Sag A* by precisely tracking the motions of 28 stars circling the black hole. The speed and orbit of each star reflects the strength of the black hole's gravity pulling on it.

The faster and tighter the orbit, the more powerful the force pulling on the star. Large telescopes equipped with "adaptive optics" systems that reduce atmospheric blurring enabled the researchers to track individual stars despite their great distance. — **D. P.**

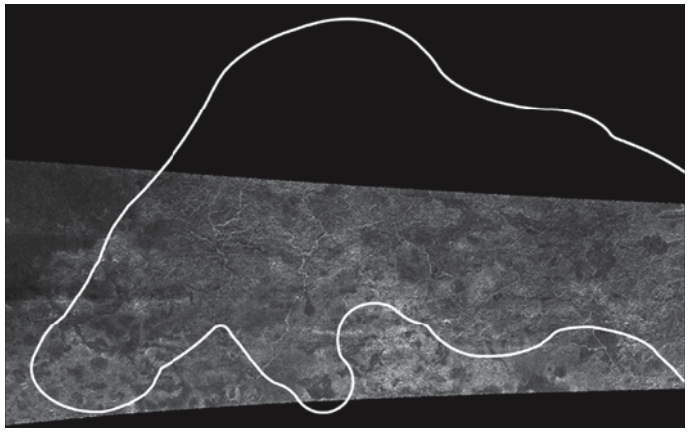
Titan's bright spots point to eruptions

Observations from recent Cassini orbiter flybys of Titan hint that icy volcanoes may be erupting superchilled liquids into the saturnian moon's atmosphere. Unlike terrestrial volcanoes, which erupt molten rock, Titan's cryovolcanoes would discharge volatile liquids such as water, ammonia, and methane. Planetary scientists reported the latest evidence December 15 at the American Geological Union's annual meeting in San Francisco.

Cassini's visual and infrared mapping spectrometer (VIMS) found two distinct regions that brightened significantly between observations a couple of years apart. During one brightening, the VIMS team detected ammonia frost — possible evidence of a recent eruption.

"The fact that we found the ammonia at times when the surface brightened strongly suggests that material was being transported from Titan's interior to its surface," says VIMS team member Robert Nelson of NASA's Jet Propulsion Laboratory in Pasadena, California.

Other scientists aren't convinced yet. Planetary geologist Jeffrey Moore of NASA's Ames Research Center at Moffett Field, California, claims Titan's interior may never have warmed enough to drive true cryovolcanism. "The flowlike features we see on the surface may just be icy debris that has been lubricated by methane rain and transported downslope like mudflows." — **RICHARD TALCOTT**



Icy volcanoes? Cassini radar imaged drainage channels cutting across a region of Titan's equatorial zone (bordered by the white line). The channels brightened significantly over time, suggesting cryovolcanism. NASA/JPL

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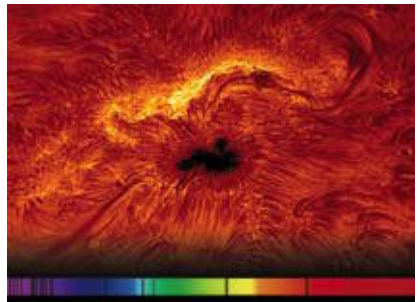

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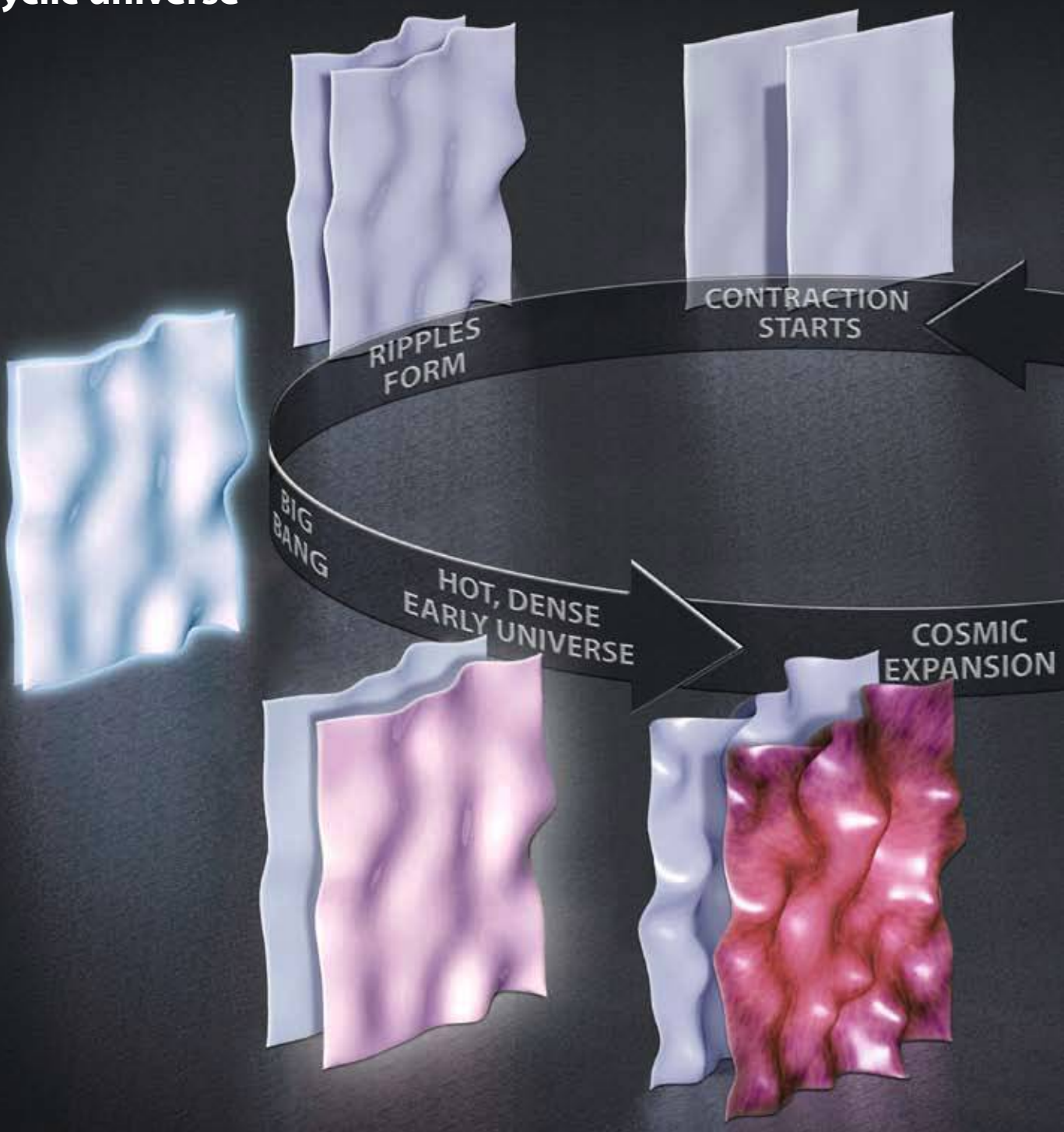
The cyclic universe



Why the universe had

The Big Bang may not have been the instant of creation, but a single event in an infinite cycle. **by Paul J. Steinhardt**

The conventional Big Bang model of the universe says our cosmic origins can be pinned down with remarkable precision. It claims that everything — space, time, matter, and energy — sprang into being some 13.7 billion years ago in a dramatic instant known as the "Big Bang." At birth, the universe occupied an infinitesimal volume filled with a hot, dense gas of matter and radiation.

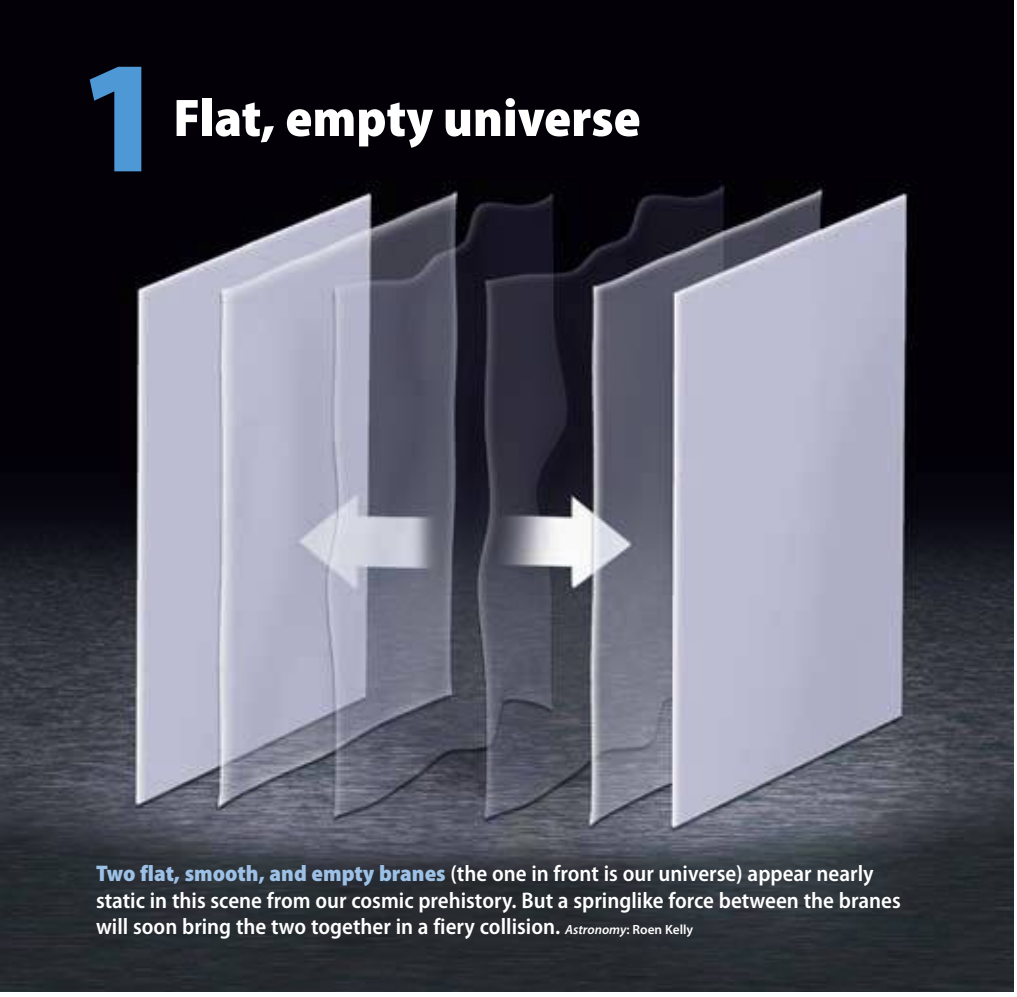
Over the course of the next 13.7 billion years, the tiny volume expanded and cooled, evolving eventually into the vast expanse of galaxies, stars, and planets we see today. And everything that has ever transpired throughout the history of the universe has occurred since that initial instant.

Or did it? Could this picture be flawed? Most cosmologists would bristle at this question. They would rise to the Big Bang model's defense by pointing to the litany of evidence that shows how the cosmos was once hotter and denser and that traces the formation of galaxies and the universe's large-scale structure. The evidence is both voluminous and detailed. Yet all these data come from events that supposedly occurred 1 or more seconds after the Big Bang. Currently, there is not a shred of empirical evidence or a reliable theory of gravity to inform us about the Big Bang itself.

In the cyclic universe model, our entire cosmos exists on a three-dimensional membrane ("brane" for short) in close proximity to a second such brane. This depiction shows our universe as the foreground brane in each pair. In the cyclic model, the Big Bang marks the moment when the two branes collide at the end of a long period of slow approach. The branes then rebound, and structure begins to form in our brane, leading to the universe we see today. Dark energy will soon come to dominate, however, pushing galaxies ever farther apart until the universe becomes empty. Springlike forces eventually bring the branes together again, repeating the endless cycle. *Astronomy*: Roen Kelly

no beginning

1 Flat, empty universe



Two flat, smooth, and empty branes (the one in front is our universe) appear nearly static in this scene from our cosmic prehistory. But a springlike force between the branes will soon bring the two together in a fiery collision. *Astronomy*: Roen Kelly

Albert Einstein's general theory of relativity, which describes how gravity works, breaks down at the high temperatures and densities near the Big Bang. Improved theories of gravity, such as string theory, do exist. Yet scientists have not developed these theories far enough to give a definite description of what actually happened at the beginning.

And this isn't the only concern. Some of the evidence cited in favor of the Big Bang picture makes sense only if scientists add major components that significantly complicate it.

A brief period of extraordinary expansion, called inflation, must smooth the universe immediately after the Big Bang and create small wrinkles in the distribution of matter to lay the seeds for galaxies. Dark matter must exist to explain the speed at which large-scale structure formed. And dark energy, or something like it, must come into play to explain the accelerating expansion of the universe discovered in the 1990s.

It appears that the uncertainties and increasing complexity associated with the standard Big Bang model leave room for an alternate theory of the history of the universe. Of course, any such new view must be consistent with existing observations of cosmic evolution.

Cyclic universe

These thoughts provided some of the motivations that led Cambridge University physicist Neil Turok and me to develop the "cyclic model of the universe." This radically new proposal offers a different idea of what happened at the Big Bang and a novel vision of our past and future.

According to this model, the universe is endless. It undergoes limitless cycles of expansion and cooling, each of which begins with a Big Bang and ends in a Big Crunch. The event that occurred 13.7 billion years ago is only the most recent bang. Although this moment created the matter contained in everything we see, space, time, and energy existed before the bang. And more Big Bangs await us in the future.

We based the cyclic model on three underlying notions. First, the Big Bang is not the beginning of space or time. Instead, it's the moment when gravitational and other forms of energy are transformed into new matter and radiation and a new period of expansion and cooling begins.

Second, bangs occurred periodically in the past and will continue periodically in the future. The cycle repeats perhaps once every trillion years. Third, the sequence of events that sets the large-scale structure of the universe we observe today took place during a long period of slow contraction that preceded the bang. Similarly, the events that will occur over the next trillion years will set the large-scale structure for the cycle to come.

Although the cyclic model differs radically from the conventional Big Bang-inflationary picture in terms of the physical processes that shape the universe and their overall outlook on cosmic history, both theories match all current observations with the same degree of precision. The two pictures will not remain indistinguishable, however. They differ significantly in their predictions of primordial gravitational waves and the fine-scale statistical distribution of matter. Scientists should be able to test these predictions during the next decade.

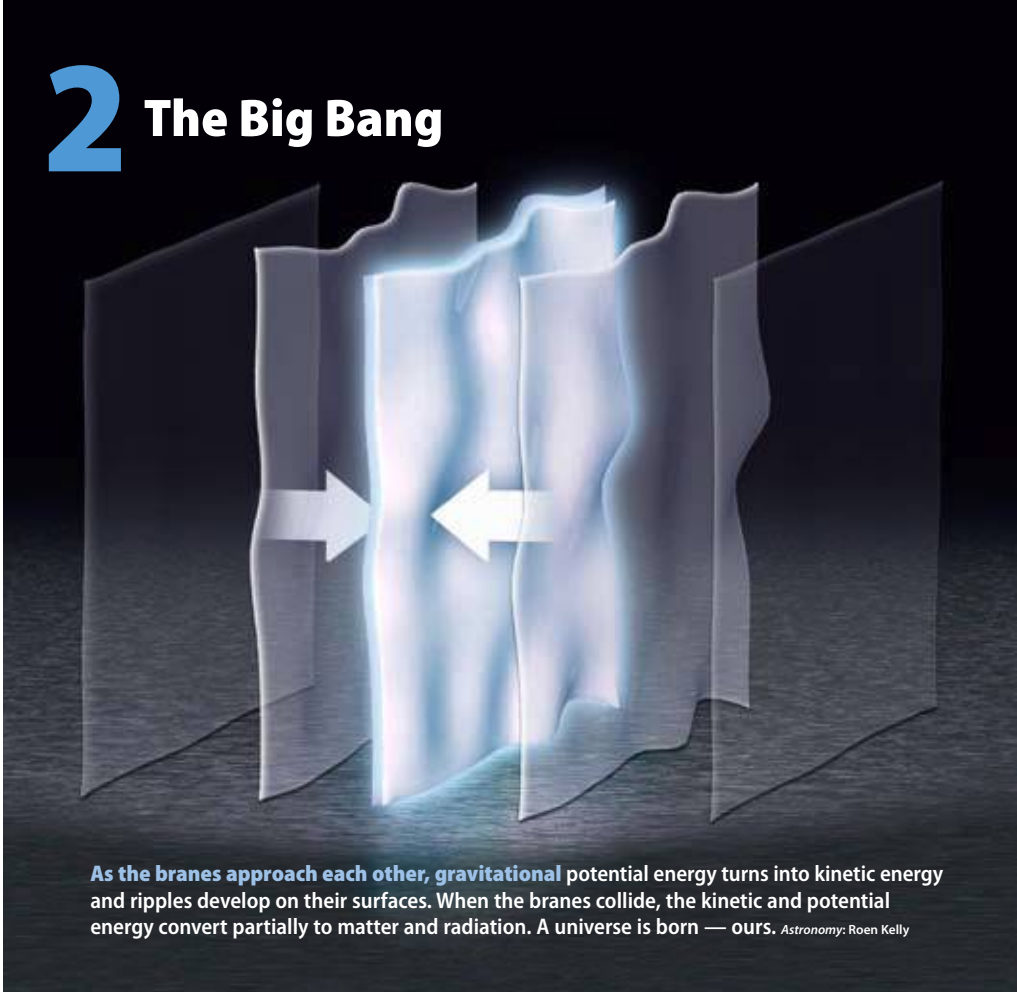
In the cyclic model, dark energy restores space to a uniform state that leads to the next bang.

Inside cosmic cycles

In the cyclic picture, hot, dense matter and radiation fills the universe immediately after the bang. The cosmic temperature reaches about 100 billion billion (10^{20}) times that of the Sun's core. At this temperature, matter breaks down into its elemental constituents: quarks, electrons, photons, and the like. Even so, the temperature remains modest compared with that expected in the usual Big Bang.

Paul J. Steinhardt *is the Albert Einstein Professor in Science and Director of the Center for Theoretical Science at Princeton University. He wrote, with Neil Turok,* Endless Universe: Beyond the Big Bang *(Doubleday Publishing, 2007).*

2 The Big Bang



As the branes approach each other, gravitational potential energy turns into kinetic energy and ripples develop on their surfaces. When the branes collide, the kinetic and potential energy convert partially to matter and radiation. A universe is born — ours. *Astronomy*: Roen Kelly

During the following 9 billion years, the cosmos expands and cools. The elemental constituents clump into protons and neutrons, and eventually atoms, molecules, planets, stars, galaxies, and larger structures all form.

At this point, some 9 billion years after the bang, the matter density of the universe drops so low that a new form of energy overtakes the universe. This "dark energy" doesn't behave like matter and more familiar forms of energy. These forms are gravitationally self-attractive and resist the expansion of the universe.

Dark energy, on the other hand, is gravitationally self-repulsive and causes cosmic expansion to speed up. This explains recent observations of distant supernovae and the cosmic microwave background radiation that prove the expansion of the universe has been accelerating for the past 5 billion years.

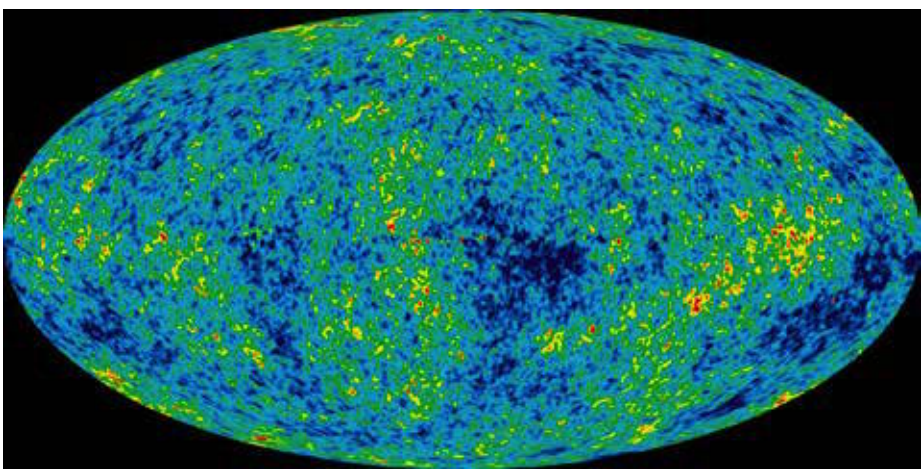
During the next trillion years, the accelerating expansion will continue and rapidly dilute the universe of the matter and lumpy structures formed since the last bang. So far, this scenario matches the conventional Big Bang model, but with an important difference. In the standard Big Bang picture, dark energy has no purpose. Theorists simply add it to the model separately to account for the observations.

In the cyclic model, we integrate dark energy into the theory, and it plays an essential role. It naturally and efficiently restores space to a simple, uniform, and pristine state that leads to the next bang — and ensures this process repeats in every cycle.

In the Big Bang model, dark energy will dominate the universe for the rest of cosmic history. It transforms space into a vacuous wasteland. In the cyclic model, dark energy is unstable. It will decay near the cycle's end into a form of extremely high-pressure energy (where pressure exceeds the energy density) that causes the universe to contract ultra-slowly.

A slowly contracting universe filled with this high-pressure form of energy produces two important effects. First, space becomes increasingly smooth and flat as the contraction proceeds. This sets those conditions leading up to and immediately after the bang. Second, quantum physics causes random fluctuations in the high-pressure form of energy. This produces tiny variations both in the contraction rate and in the time when new matter and radiation fill different regions of space.

These two effects combine to create an almost perfectly smooth universe after the bang. The only deviations: a pattern of tiny temperature variations just like those observed in the cosmic microwave background radiation, and tiny variations in the concentration of matter just like those needed to explain the current distribution of galaxies.



The cosmic microwave background radiation supports the Big Bang model of the universe's creation, but it also agrees with the cyclic universe model. Tiny temperature fluctuations, which show up here as color differences, are the seeds around which galaxy clusters formed. NASA/WMAP Science Team

Braneworlds in the cyclic model

Developments in string theory inspired the cyclic model. Chief among these are the ideas of braneworlds and extra dimensions. ("Braneworld," often called simply "brane," is short for "membrane-like world.") Although the cyclic model does not require these ideas — or even

3 The universe today

After the collision, the branes separate and the hot, dense universe expands and cools. The ripples from the previous stage cause the slight temperature variations that show up in the cosmic microwave background radiation and form the seeds for large-scale structure. Nearly 14 billion years later, galaxies and galaxy clusters dominate the universe. *Astronomy*: Roen Kelly

string theory, for that matter — they suggest an intuitive and appealing geometrical interpretation of the cyclic model.

According to a version of string theory known as M theory, our entire three-dimensional universe is actually a braneworld embedded in a space possessing four spatial dimensions. And our braneworld lies a microscopic distance from a second three-dimensional braneworld. In the full version of string theory, six additional dimensions exist, but they play a minor role in the cyclic cosmology that we can ignore.

The braneworlds are elastic — they can expand, wiggle, and warp. They can also move around. The laws of string physics constrain matter on our brane to move only in our three dimensions. Consequently, we cannot reach into the fourth spatial dimension or see, touch, or feel the neighboring braneworld. However, gravity attracts the braneworlds to each other, and additional fields can generate springlike forces between the braneworlds.

In the braneworld depiction, the gravitational and springlike forces drawing the two braneworlds together cause regularly repeating collisions — the cyclic model in a nutshell. The collision itself produces a Big Bang.

This picture immediately makes it clear that the Big Bang does not represent the "beginning." A collision necessarily implies that the braneworlds — that is, space and time — exist before and after the bangs. The bang merely marks the moment of collision when some of the gravitational potential energy and braneworld kinetic energy convert into hot matter and radiation and return the universe to a high temperature and matter density. After the bang, the branes bounce apart and begin to stretch along the three large dimensions. This causes the matter and radiation to expand, cool, and clump into the large-scale structure we see today.

The new dark energy

In this view, dark energy is the gravitational potential energy stored in the springlike forces that draws the branes together. Once the branes have stretched enough that this stored energy density exceeds the matter density, the stretching of the branes speeds up. This explains the accelerating expansion observed today.

Unlike the standard Big Bang model, however, this phase won't last forever. Eventually, after perhaps a trillion years, the accelerated expansion of the branes stops and the springlike forces draw the branes together. At the next collision, some of the potential and kinetic energy converts to new matter and radiation. Not only does gravitational energy add to the collision's impact, its contribution ensures that the spring never winds down and the collisions can continue forever.

In the colliding braneworld picture, the cycling reflects the expansion and

The Hercules galaxy cluster (Abell 2151) epitomizes the universe today. Rich galaxy clusters like this congregate into even larger and more massive superclusters, which form the backbone of cosmic large-scale structure. CFHT/Jean-Charles Cuillandre/Coelum

Europe's Planck spacecraft may settle the debate between the Big Bang and cyclic models within a decade. Planck will search for the tiny but measurable difference between the two theories as it examines the cosmic microwave background at unprecedented sensitivity. ESA

contraction of the extra dimensions. The two braneworlds themselves expand throughout. In this sense, the cyclic model really becomes a hybrid — steady growth occurs along the usual three dimensions while periodic oscillations occur along the extra dimension.

Which picture is right?

The cyclic model and the Big Bang model produce remarkably different pictures of the past history and future evolution of the universe. In the Big Bang view, the Big Bang marks the beginning of time, so the universe is only 13.7 billion years old. A period of inflation after the Big Bang sets the large-scale structure of the universe.

Theorists introduced dark energy to explain the universe's current accelerating expansion, but otherwise it serves no needed role. Once introduced, however, dark energy dominates the future of the universe. It will turn the space we observe into an eternal, dark, vacuous wasteland.

In contrast, the cyclic view says 13.7 billion years represents only the time since the last bang and the creation of the matter and radiation we see today. The universe has had many such cycles — perhaps infinitely many — prior to the present one. And the true age of the universe is far more than 13.7 billion years.

The theory has no need for inflation because large-scale structure derives from events that lead up to each bang. Dark energy is an essential element integrated into the cosmology. The future becomes more hopeful: Although space will become dark and vacuous for a period, a new cycle eventually will begin. The space we observe will be infused with new matter, galaxies, stars, planets, and life.

Although the two theories explain equally well all the astronomical and cosmological observations scientists have collected thus far, two key tests will be able to distinguish them. First, inflation produces a spectrum of detectable gravitational waves. These wrinkles in space propagate through the universe and should produce a measurable polarization pattern in the cosmic microwave background radiation. The cyclic model has no period of inflation and produces gravitational waves far too weak to be detected.

Second, the inflationary picture predicts that the statistical distribution of temperature variations in the cosmic microwave background should follow a bell curve almost precisely. The cyclic model predicts a larger, measurable deviation from a bell curve.

During the next decade, scientists will conduct a number of experiments capable of detecting polarization and our predicted deviations in the cosmic microwave background radiation. First up: the European Space Agency's Planck mission, scheduled for launch this year.

The outcome of these experiments should determine which cosmic history is correct — and whether the future will be a vast wasteland or a precursor that leads to cosmic rebirth.

See a computer simulation of the cyclic universe at www.Astronomy.com/toc.

4 Dark energy dominates

In the distant future, the cosmos keeps spreading out faster and faster as its stored energy density exceeds its matter density. This is what we perceive as dark energy, which started to have an effect some 9 billion years after the bang. The whole cycle from one bang to the next takes roughly 1 trillion years. *Astronomy*: Roen Kelly

Is Earth one

Ten years ago astronomers thought our planet was really, really special. New observations suggest it may not be so rare. **by Ray Villard**

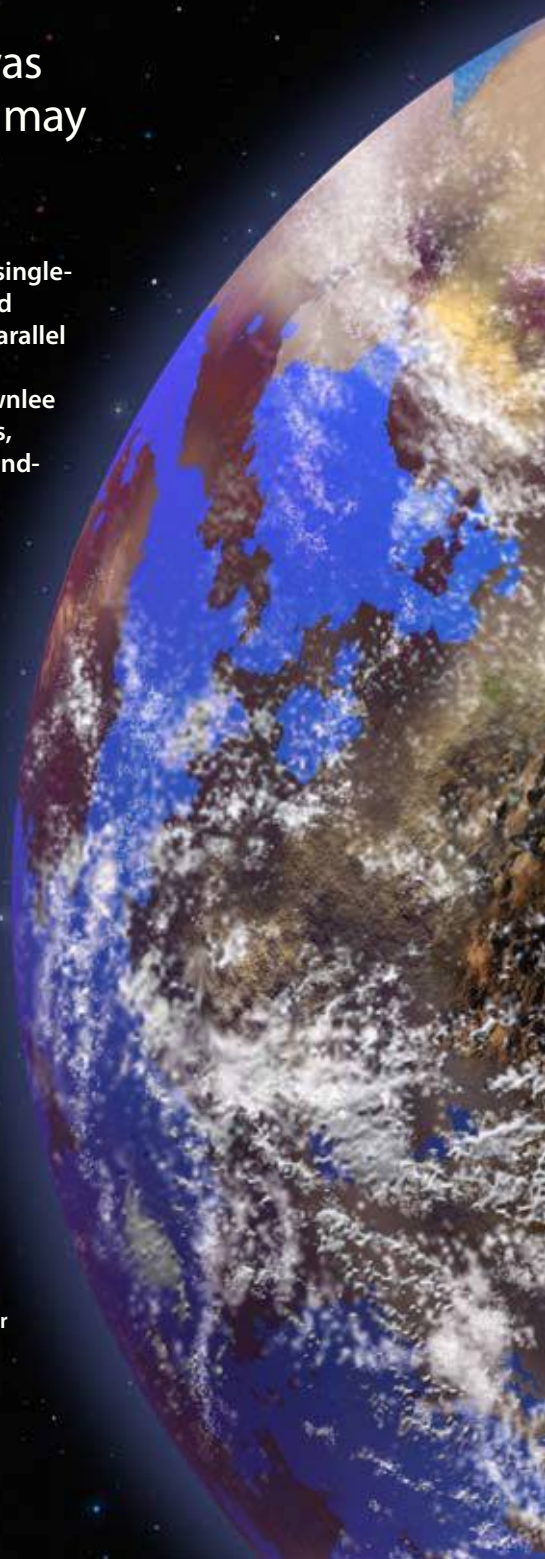
Before the end of the next decade, we could find an earthlike planet. Less than a decade after that, we might determine it has some form of life altering its atmosphere. But we can't predict whether such an Earth clone harbors complex life, or, above all, intelligent life.

The odds are unlikely, if not zero, according to a popular-level book titled *Rare Earth: Why Complex Life Is Uncommon in the Universe* written by paleontologist Peter D. Ward and astronomer Donald Brownlee and published in 2000. The authors, both then at the University of Washington, maintain that the sweeping diversity of complex life on Earth arose out of an extraordinary set of geological watersheds and astrophysical conditions. Furthermore, this string of chance events would be extremely hard to duplicate elsewhere in the universe.

Ward and Brownlee acknowledge that many planets throughout the galaxy may be teeming with microbial life. But they believe that the forces of biological evolution rarely advance life beyond the single-cell stage if planetary conditions and physical evolution are not exactly parallel to what happened on our planet.

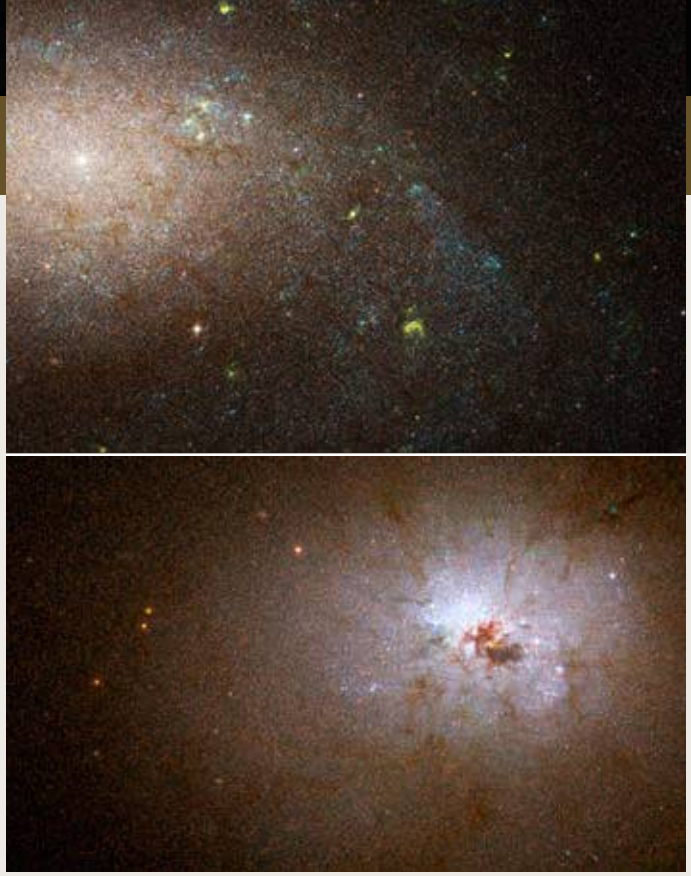
Now, 9 years after Ward and Brownlee published the Rare Earth hypothesis, astronomers have a better understanding of the diversity of planets and planetary systems, the role stellar evolution plays in planetary formation, and the adaptability and tenacity of life as gleaned from astrobiology lab experiments. This makes parts of the Rare Earth hypothesis testable today, and others will be even more so in the future. Unfortunately, the parts related to life's evolution may never be testable unless we actually find a planet inhabited by complex organisms. We can, however, compare some of the book's major astronomical claims with what astronomers have observed.

Ray Villard *is the news director of the Space Telescope Science Institute in Baltimore.*



An Earth clone harboring complex life may not be as rare as once believed. New research in astrobiology, stars, galaxies, and extrasolar planets shows that the events and precise conditions that encouraged life to evolve on Earth may occur on planets in other solar systems. Lynette Cook

# of a kind?



These two images from the 2008 ACS Nearby Galaxy Survey Treasury (ANGST) project photographed by the Hubble Space Telescope show the diversity among galaxies. NGC 300 (top) is a spiral galaxy with young and hot blue stars and glowing hot yellow blobs of gas. NGC 3077 (bottom) is a much smaller galaxy that is being torn apart by its neighboring galaxies, as seen by the dark clumps of material near its galactic nucleus. NGC 300 is about 7 million light-years from Earth, and NGC 3077 is roughly 12.5 million light-years away. NASA/ESA/J. Dalcanton and B. Williams (University of Washington)

1 Earth's elements are rare.

An earthlike planet would have a rocky mantle surrounding a hot metallic core laden with radioactive elements from supernova debris. Astronomers call elements heavier than helium "metals." We know from extrasolar planet observations that stars with more of these metals than the Sun are even more likely to have planets. Surveys by exoplanet hunting sleuth Geoff Marcy of the University of California at Berkeley show that 25 percent of the most metal-rich stars harbor planets, while only 3 percent of low-metal stars have planets.

In a 2001 paper, Guillermo Gonzalez, then of the University of Washington, and Brownlee proposed that galaxies have a "galactic habitable zone" (GHZ) that contains the right mix of heavy elements for building earthlike planets. In our galaxy, the Sun is located within the roughly 6,000-light-year-thick GHZ ring.

But not all stellar astronomers subscribe to this idea. Metallicity changes only slightly across the 100,000-light-year-diameter Milky Way disk. Heavier elements are more abundant toward the core and less so at the edge.

Gonzalez and Brownlee concluded that the GHZ "can be extrapolated across the universe as a whole." But a 2008 Hubble Space Telescope survey of 69 galaxies within 30 million light-years of the Milky Way shows that star formation and the distribution of heavy elements vary from galaxy to galaxy, and even within each galaxy. When you look at this level of detail, there is no such thing as a "typical" galaxy, concluded the survey researchers led by Julianne Dalcanton of the University of Washington.

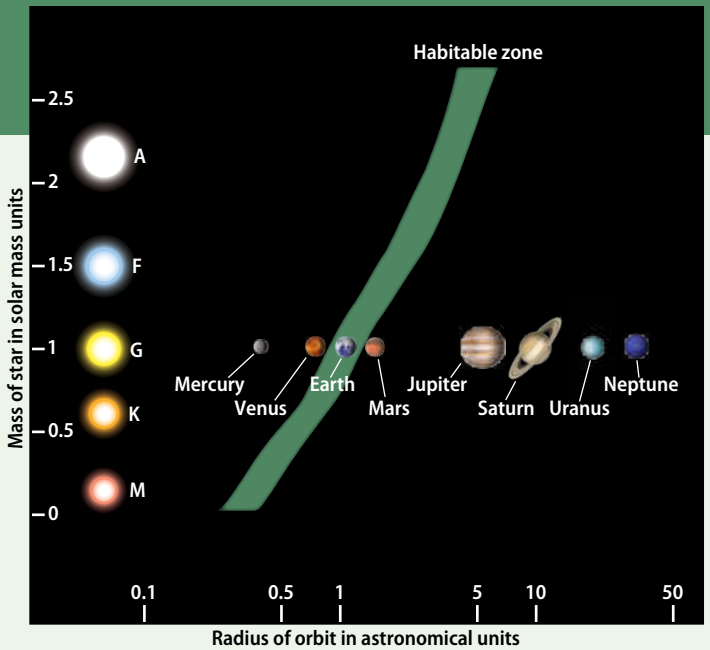
2 A planet with advanced life must be at the right distance from its star to ensure that water remains liquid.

In the late 1970s, Michael Hart, then of NASA, developed the idea of a stellar habitable zone (HZ) where liquid water on a planet's surface could remain stable for billions of years. This is a narrow zone where Earth fortuitously wound up.

All stars have HZs. While stars hotter than our Sun have wider zones, those stars are shorter lived compared with the Sun. Assuming complex life typically requires several billion years to evolve, those stars don't give life much of a chance for complexity and diversity. Conversely, the long-lived red dwarf stars have narrow HZs close to the stars and are much longer lived.

NASA's Kepler mission, scheduled at press time to launch in March, will tell us the frequency of earthlike planets in HZs. Kepler will look at 100,000 nearby stars in the direction of our galaxy's Orion Arm. It will measure slight dips in a star's light as a signature of a planet transiting the face of the star. Repeated dips in light will provide the planet's orbital period.

If Earth-sized planets are common, then Kepler should detect hundreds of them. Some of those planets are sure to be in the star's HZ.



A star's habitable zone depends on the star's mass, size, and temperature. Planets in this zone can support liquid water on their surfaces; it's not too hot or cold. Hotter and larger A-type stars have wide habitable zones that are farther from the star. Cooler and smaller M-type stars have narrow habitable zones that are closer to the star. *Astronomy*: Theo Cobb after James Kasting et al

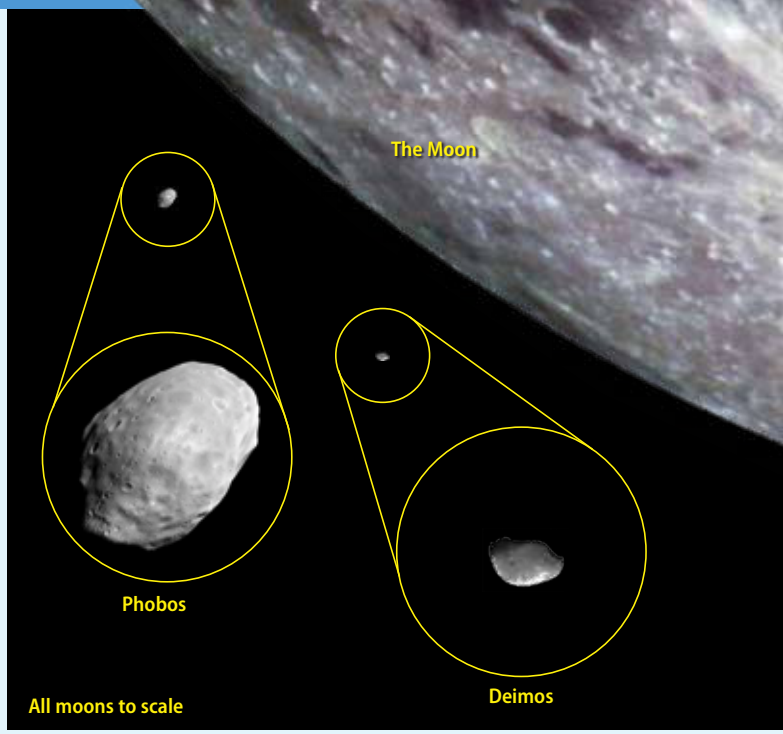
3 A planet needs a large moon at just the right distance to minimize changes in the planet's tilt, ensuring climate stability.

Earth has remained inclined at roughly 23.5° for billions of years. This moderates temperature across the globe. In 1993 Jacques Laskar of the Bureau des Longitudes in Paris and colleagues calculated that, without the Moon to stabilize Earth's rotation, Earth's tilt would vary dramatically between 0° and 83°. The harsh temperature extremes imposed by a wandering orientation toward the Sun would likely challenge life's evolution.

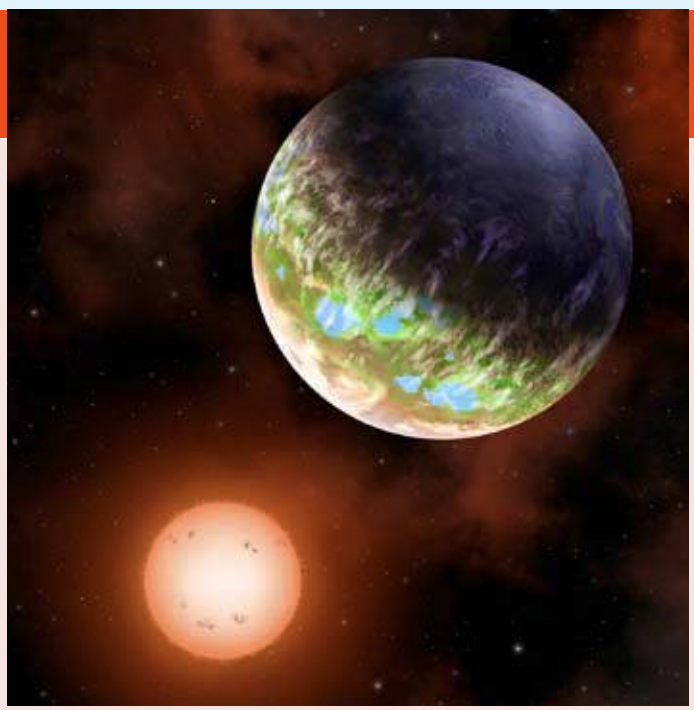
Mars, which has only two tiny moons, has experienced axial tilts between 13° and 40° over 10 to 20 million years. When Mars' axial tilt is high, the northern polar cap points directly toward the Sun, causing dramatic climatic shifts.

To find planets with large moons, we need to look for evidence of collision processes around stars. The Moon was born from an impact between Earth and a Mars-sized planetoid 4.4 billion years ago. Pluto's moons Charon and two small satellites emerged from a collision between Pluto and another icy Kuiper Belt object.

In 2007 the Spitzer Space Telescope observed 400 young stars and found only one of them immersed in the telltale dust of interplanetary collisions. Taking into account the time that dust should stay around and the age range when collisions like this should occur, Nadya Gorlova of the University of Florida and her team calculated that large moons orbiting terrestrial planets should form in only 5 to 10 percent of planetary systems.



Earth's Moon is substantially larger than Mars' moons, Phobos and Deimos. Astronomers suspect our Moon's size keeps Earth's tilt stable; Mars' tilt ranges from 13° to 40° over millions of years. Moon: NASA/JPL/USGS; Phobos: NASA/JPL/Malin Space Science Systems; Deimos: NASA/ JPL Viking Project



A terrestrial planet orbiting in the habitable zone of a red dwarf star would be tidally locked. The star-facing side would scorch while the farside would freeze. A temporal band, however, might exist between the two extremes. If the planet had a thick atmosphere and ocean currents, those features could stabilize the temperature, possibly allowing life to evolve. Lynette Cook

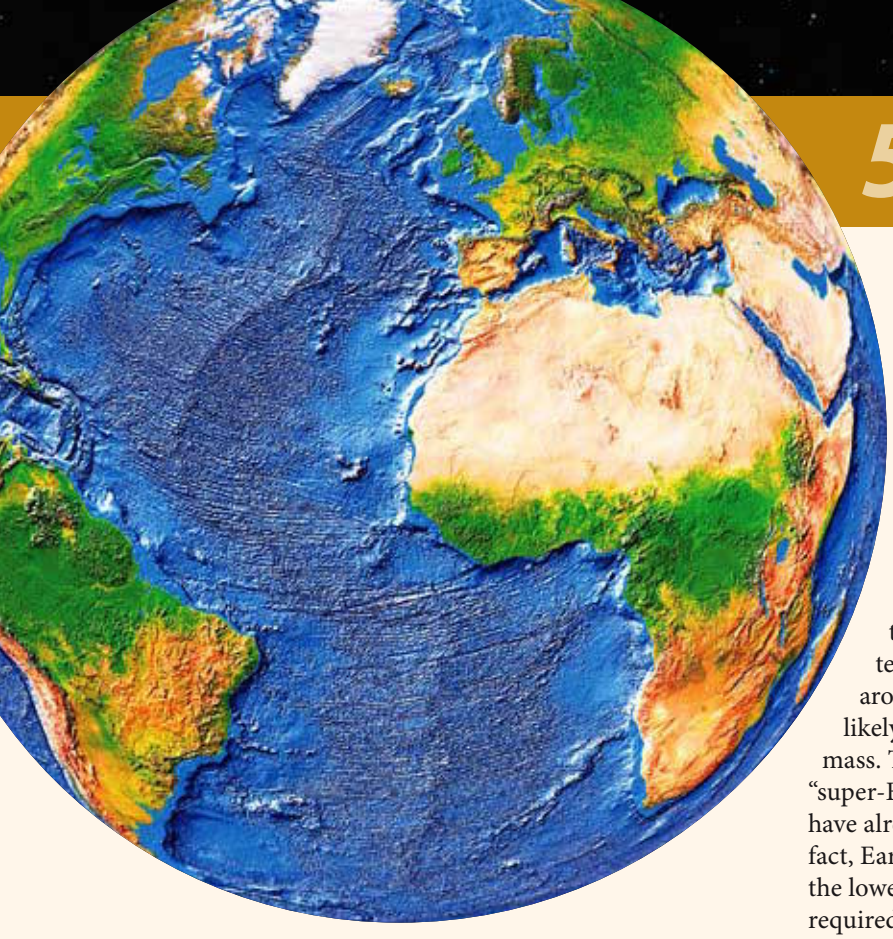
4 Only 10 percent of the stars in our galaxy are Sun-like.

So what? Red dwarf stars may be ideal candidates for inhabited planets. They are almost 10 times as abundant as the Sun. Life on a planet orbiting a red dwarf would have many billions of years to evolve because the star lives much longer than the Sun. Earth has only about 1 billion years left before the Sun becomes so hot that it evaporates the oceans and makes Earth lifeless.

Planets in a red dwarf's HZ would be so close to the star that they likely would be tide-locked, with one hemisphere permanently facing the star (just as the Moon keeps one hemisphere toward Earth). Tide-locked worlds are easily dismissed as uninhabitable because the star-facing side bakes and the farside freezes.

A recently published study led by Jean Griessmeier of the Observatory of Paris concluded that a tide-locked planet would have a weak magnetic field. The star's dense stellar wind would pound that magnetic field, and huge coronal mass ejections would erode the planet's atmosphere.

But a planet more massive than Earth that retains a deep global ocean could have a thick cloudy atmosphere to absorb incoming particle strikes. A planet with such an atmosphere and ocean might also be able to moderate its climate.



Earth's plate tectonics is crucial to our planet's moderate temperature. Our planet is the only one in our solar system that has active plate tectonics, which explains the temperate weather (compared to Mars and Venus). This image, based on NASA data, highlights the Mid-Atlantic Ridge, the boundary where the North American and European plates spread apart.

NASA Earth Observatory/Francis Reddy/*Astronomy*: Roen Kelly

5 A planet needs plate tectonics to help regulate its temperature.

Plate tectonics help keep planetary temperatures consistent by recycling carbon. It also promotes biodiversity by producing mountain chains and other kinds of environmental complexity.

Scientists estimate that the majority of terrestrial planets around other stars are likely a few times Earth's mass. They call these planets "super-Earths." Astronomers have already found several. In fact, Earth's mass may be at the lower boundary of a required mass for maintaining conditions for the evolution of advanced life.

A "super-Earth" would have a much hotter core because of a larger volume of hot radioactive elements in its interior. A hotter core would likely drive plate tectonics more vigorously than on Earth. Some computational models predict a super-Earth would have thinner crustal plates than Earth. Many of these worlds would be "aqua-planets" with deep oceans and no continents.

Other computational models, however, predict that because of the large size of super-Earths, crustal plates might strengthen under the greater pull of gravity or under the crushing pressure of a super ocean. In these models, the planet's crust wouldn't break into large, active plates.

There might be a narrow range of masses for terrestrial planets, where the planet needs just the right mass for plate tectonics.

6 An earthlike planet needs a Jupiter-like planet to deter the rain of killer meteorites and allow life to evolve into advanced communities.

George Wetherill, then at the Carnegie Institute, estimated that the rate of impacts on Earth could be as much as 10,000 times higher if Jupiter weren't present to deflect comets from the Kuiper Belt and Oort Cloud. Saturn, at less than one-third the mass of Jupiter, would be marginally effective.

How abundant are "Jupiters" as "protector planets?" A detailed 2008 survey of Orion Nebula stars by Joshua Eisner, then at the University of California at Berkeley, and colleagues determined that fewer than 10 percent of stars have enough surrounding dust and gas to assemble Jupiter-sized planets. A torrent of radiation from the most massive stars in a star-forming region ablates the individual disks. The Hubble Space Telescope revealed tadpole-shaped circumstellar environments where the planet-forming dust and gas disk is being blasted away from the star by a nearby massive star.

However, in a recent Spitzer Space Telescope survey, astronomers led by Thane Currie of the Harvard Smithsonian Center for Astrophysics studied the 5 million-year-old star cluster NGC 2365. They found that all stars with masses of the Sun or greater have lost their protoplanetary disks. The astronomers conclude that gas giants must form in less than 5 million years, or they probably won't form at all.

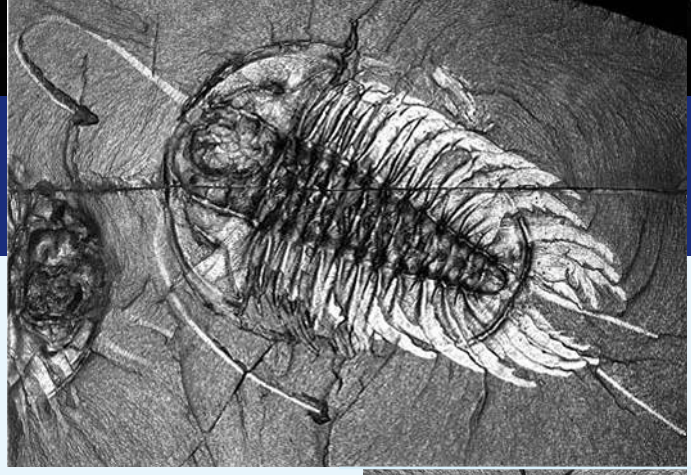
Four young stars in the Orion Nebula sport probable protoplanetary dust and gas disks in this Hubble Space Telescope image. New research suggests, however, that fewer than 10 percent of protoplanetary disks contain enough stuff to form a Jupiter-sized planet. C.R. O'Dell/Rice University NASA/ESA

7 *Life's Cambrian "explosion" was a singular event that fostered the appearance of complex life on Earth.*

Earth experienced a series of game-changing events over the 3.5 billion years that elapsed since life first appeared. One of the biggest mysteries in life's evolution is the seemingly rapid appearance and diversification of most major groups of complex life-forms between about 543 million years ago and 490 million years ago during the Cambrian era. Scientists continue to debate what might have caused such rapid evolution — if in fact it was "rapid," or scientists just don't have fossils to complete the evolutionary track.

Among many alternative ideas, Ward and Brownlee proposed that a chance geological upheaval where Earth became cold and ice covered, even near the equator, advanced life's evolution. The first of these "Snowball Earth" eras occurred 2.5 billion years ago and the second about 550 million years ago.

On the other hand, the Cambrian explosion simply may be a common evolutionary threshold routinely crossed in life's development on an earthlike planet. Genetic complexity arises and allows a range of creatures to appear. A random number of geological upheavals may or may not have something to do with life's evolution.



Fossil records from the Cambrian era — roughly between 543 and 490 million years ago — represent most modern-day animal groups. Scientists haven't found many fossils of animal descendents dating prior to the Cambrian; therefore, they call this "explosion" of life the Cambrian explosion. While this is one piece of evidence for a rare Earth, the sudden appearance of life may instead be the result of fewer fossils from earlier eras. Shown above is an Olenoides serratus (a trilobite) specimen; on the right is Waptia fieldensis (a crustacean). Courtesy of Smithsonian Institution

Is Earth rare?

Given the vast number of stars in our Milky Way, astronomers predict our galaxy may hold as many as one trillion planets. Even if one out of one million meets the above-described conditions, our galaxy still would contain at least one million Earth clones.

A fundamental problem with the Rare Earth hypothesis is that it makes projections from a narrow extrapolation of what astronomers know today. This occasionally happens in science, and when it does, it is a failure of imagination. A little more than 100 years ago, the great British scientist Lord Kelvin proposed that radio waves had no practical use, X rays were a hoax, and heavier-than-air flight was impossible. Only 25 years before the development of the nuclear bomb, Nobel Laureate Robert Millikan said that humans would never tap the power of the atom.

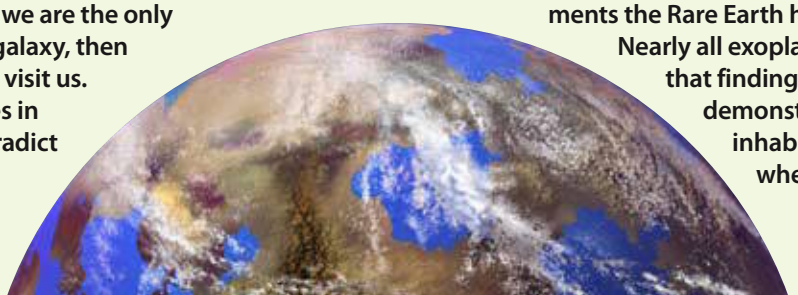
However, the Rare Earth hypothesis coincides with the Fermi Paradox about the absence of evidence for extraterrestrials. The Fermi Paradox postulates that we should have already made contact with extraterrestrial civilizations, considering the galaxy's age. The Rare Earth hypothesis offers a solution to this paradox: If we are the only advanced life-form in the galaxy, then there's no one out there to visit us.

Two overarching themes in astronomy, however, contradict the Rare Earth hypothesis. First, the universe is quite diverse across all scales. We should expect to continue finding diverse planetary systems conducive to the development and survivability of advanced life.

Life itself is now considered more diverse than once thought. A 2007 National Research Council report titled *The Committee on the Limits of Organic Life in Planetary Systems* cautioned that lab experiments today suggest life might be based on molecular structures substantially different from systems used by life on Earth. What's more, if life is possible in solvents other than liquid water, it might exist in a wider range of planetary environments.

The second theme is the Copernican Principle. More than 460 years ago, Nicolaus Copernicus hypothesized that Earth is not in the center of the cosmos but orbits the Sun along with the other known planets. In subsequent decades astronomers discovered that we are not at the center of the galaxy and the galaxy is not at the center of the universe. (In fact, the universe doesn't have a center.) The final act may be the recognition that life, both simple and advanced, is much more ubiquitous than we imagine today. The Rare Earth hypothesis is fundamentally anti-Copernican. And Copernicanism is crucial to most successful major scientific theories.

Future planet surveys, discoveries in astrobiology, and exoplanet chemistry will continue to chip away at the arguments the Rare Earth hypothesis proposed. Nearly all exoplanet astronomers agree that finding earthlike worlds and demonstrating they are in fact inhabited is only a matter of when, not if.



The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

April 09

Mercury meets the Pleiades

Besides Earth, seven other major planets populate our solar system. Of these, six will grace April's night sky. If that's not enough, the Moon will occult Venus April 22 in a spectacular morning event for many North American observers.

But first, you'll see Mercury pop out of the Sun's glow after sunset. It's positioned beautifully next to the Pleiades star cluster in Taurus as April ends. This is Mercury's best evening appearance of 2009. Saturn also puts on a grand show, and it lasts nearly all night.

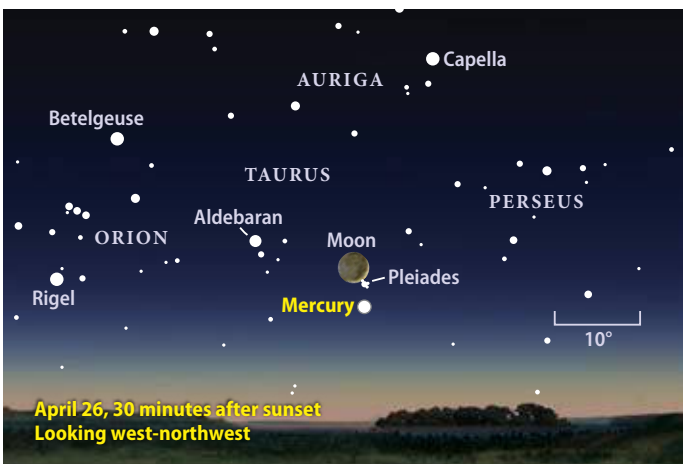
Jupiter and Neptune congregate in the early morning sky. You won't have any problem finding brilliant Jupiter, but you'll need binoculars to spot Neptune. Venus and Mars arrive with the dawn's first light, when they hang low above the eastern horizon.

The Moon and Mercury show up nicely on April evenings. The two appear closest April 26, when the Moon is a slim crescent. This predawn view of the pair was taken last July in Australia. Mike Salway

Mercury puts on a fine show starting the second week of April. Following April 8, the innermost planet appears progressively higher each night as its angular distance from the Sun increases. Mercury shines as bright as the sky's brightest star, Sirius, April 9. The planet then sets 50 minutes after the Sun. Even though it fades as the days go by, Mercury still outshines Rigel and Betelgeuse in mid-April when it sets more than 80 minutes after sunset. During the month's final 2 weeks, Mercury closes in on the spectacular Pleiades star cluster, also known as the Seven Sisters and cataloged as M45.

Don't miss a stunning sight around 9 P.M. local daylight time April 26 when a crescent Moon joins Mercury and the Pleiades in the deepening

— *Continued on page 45*



Mercury lies near the Pleiades star cluster after sunset in late April. The Moon joins this pair April 26. *Astronomy:* Roen Kelly

40 Mercury puts on a show
45 Meteor watch
45 Rising Moon
46 When to view the planets
46 Saturn's moons on parade
46 Comet search
47 Locating asteroids
47 The Moon slides past Venus

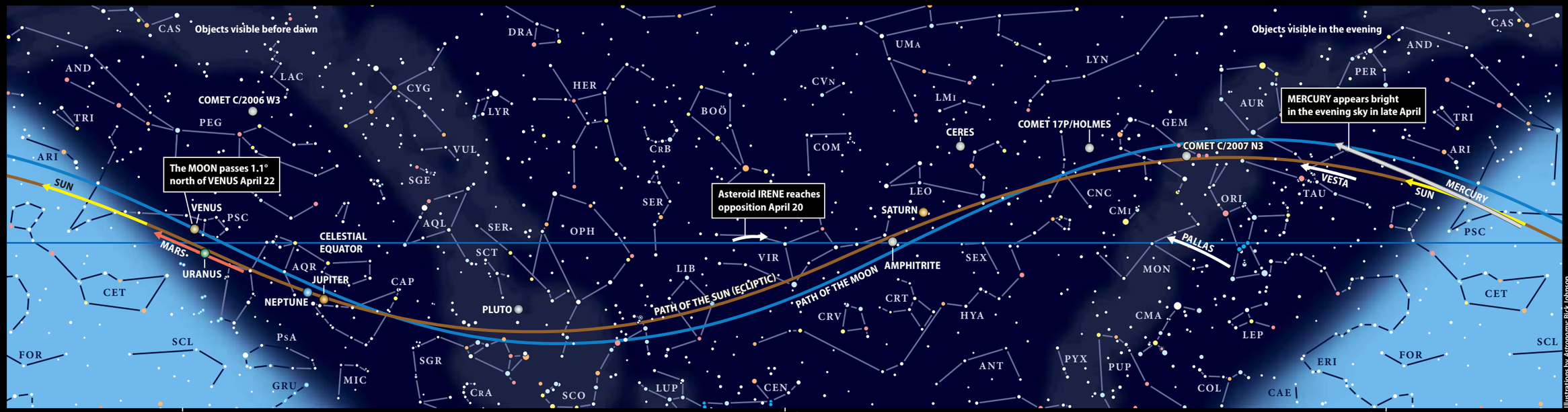
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Planets in April 09

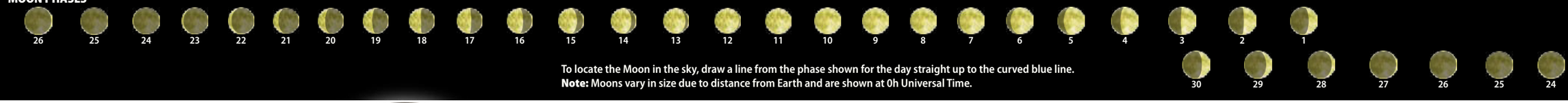
This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets

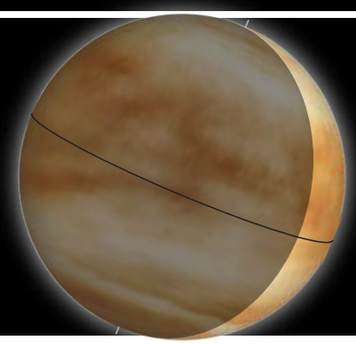


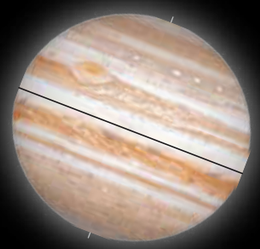
MOON PHASES

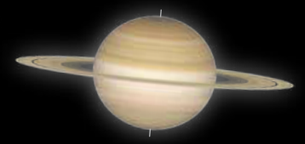


To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	April 30	April 15	April 15	April 15	April 15	April 15	April 15	April 15	April 15
Magnitude	0.7	−4.6	1.2	7.7	−2.1	0.7	5.9	7.9	14.0
Angular size	8.7"	50.7"	4.4"	0.7"	36.2"	19.3"	3.4"	2.2"	0.1"
Illumination	27%	11%	96%	97%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.774	0.329	2.140	1.855	5.445	8.601	20.954	30.353	31.243
Distance (AU) from Sun	0.383	0.723	1.382	2.554	5.079	9.397	20.099	30.031	31.629
Right ascension (2000.0)	3h45.8m	23h49.5m	23h39.8m	10h32.0m	21h36.1m	11h10.6m	23h40.2m	21h52.8m	18h13.1m
Declination (2000.0)	22°39'	4°07'	−3°27'	25°01'	−14°57'	7°44'	−2°56'	−13°16'	−17°38'

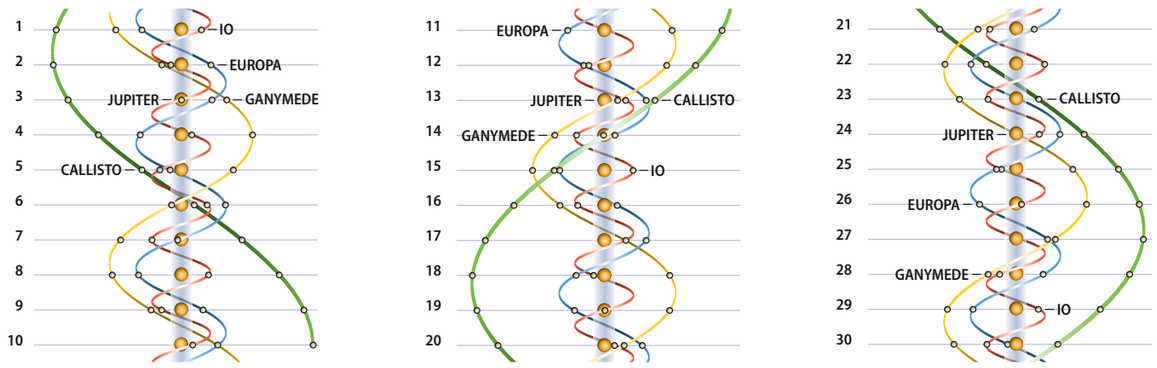






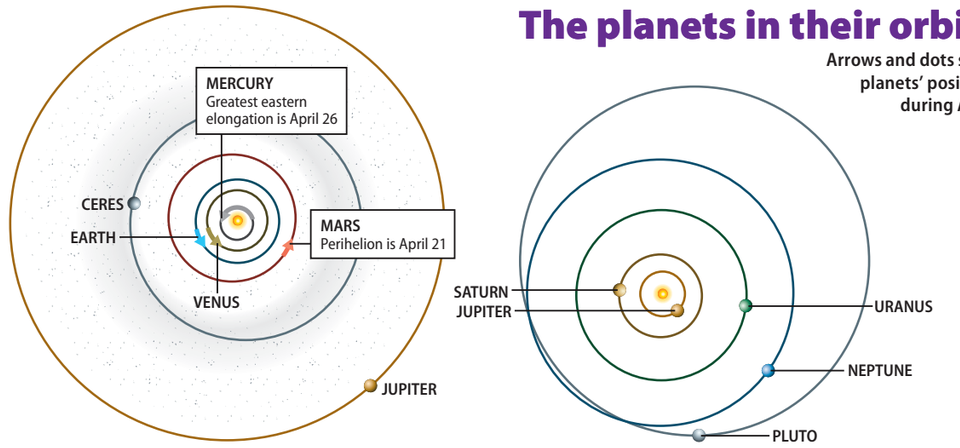
Jupiter's moons

Dots display positions of Galilean satellites at 6 A.M. EDT on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

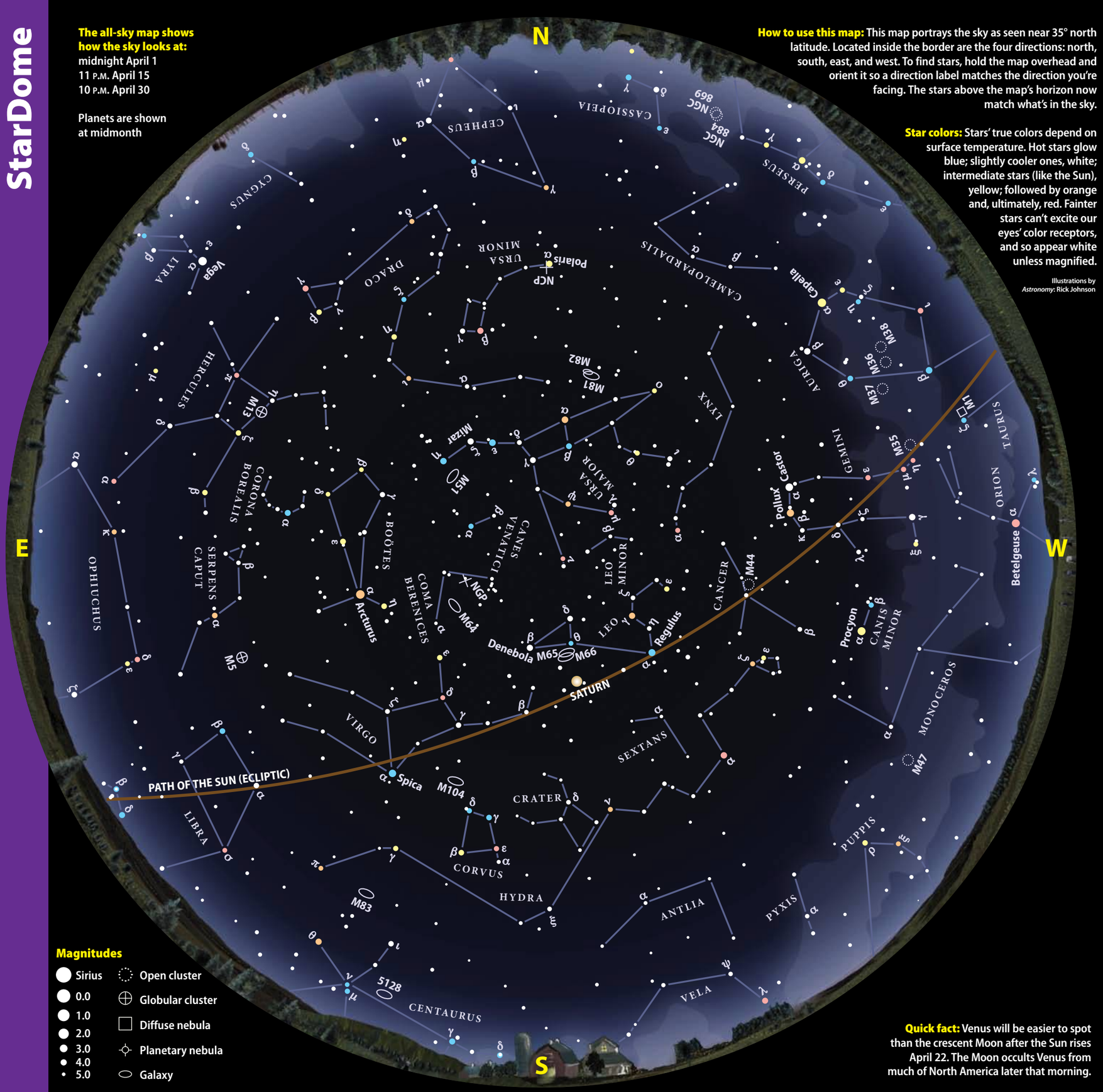
Arrows and dots show planets' positions during April.



StarDome

The all-sky map shows how the sky looks at:
midnight April 1
11 P.M. April 15
10 P.M. April 30

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Rick Johnson

Quick fact: Venus will be easier to spot than the crescent Moon after the Sun rises April 22. The Moon occults Venus from much of North America later that morning.

April 09

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Calendar of events

1 The Moon is at perigee (229,916 miles from Earth), 10:17 P.M. EDT

2 First Quarter Moon occurs at 10:34 A.M. EDT

7 The Moon passes 6° south of Saturn, 3 A.M. EDT

9 Full Moon occurs at 10:56 A.M. EDT

13 The Moon passes 0.4° north of Antares, 9 A.M. EDT

14 Mars passes 0.5° south of Uranus, midnight EDT

16 The Moon is at apogee (251,178 miles from Earth), 5:15 A.M. EDT

17 Last Quarter Moon occurs at 9:36 A.M. EDT

18 Venus passes 6° north of Mars, 1 P.M. EDT

19 The Moon passes 2° north of Jupiter, noon EDT

The Moon passes 2° north of Neptune, 8 P.M. EDT

20 Asteroid Irene is at opposition, 4 P.M. EDT

21 Mars is at perihelion (128.4 million miles from the Sun), 6 A.M. EDT

22 The Moon passes 5° north of Uranus, 4 A.M. EDT

The Lyrid meteor shower peaks

The Moon passes 1.1° north of Venus, 10 A.M. EDT

The Moon passes 6° north of Mars, 3 P.M. EDT

24 New Moon occurs at 11:23 P.M. EDT

26 Mercury is at greatest eastern elongation (20°), 4 A.M. EDT

The Moon passes 1.9° north of Mercury, noon EDT

Special observing date

26 Mercury puts on its best evening show of 2009 for observers in the Northern Hemisphere. Look for it low in the west shortly after the Sun sets.

28 The Moon is at perigee (227,446 miles from Earth), 2:25 A.M. EDT

For definitions of terms, log onto www.Astronomy.com/glossary.

Astronomy magazine

— *Continued from page 40*
twilight. The Moon lies 2° above the cluster and Mercury sits 3° below the cluster. Binoculars will provide the best view. The dark side of the Moon will be clearly visible, illuminated by earthshine.

On April 29, Mercury lies about 3 Moon-widths south of the Pleiades. The Moon has climbed significantly higher and now stands in the midst of Gemini. Mercury has dimmed to the brightness of Aldebaran, the nearby 1st-magnitude star in Taurus.

Viewing Mercury through a telescope remains challenging. The planet's disk reveals little. Its low altitude in the sky and its visibility shortly after sunset leaves observers viewing the disk while Earth's atmosphere remains turbulent. The unsteady air yields less-than-steady images.

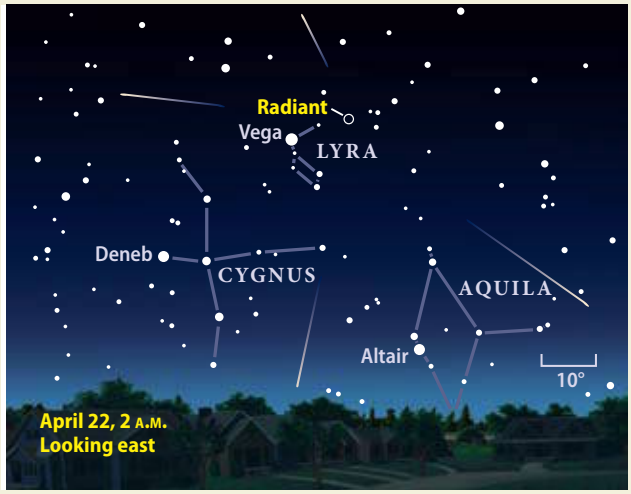
Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire.* **Alister Ling** *is a meteorologist for Environment Canada in Edmonton, Alberta.*

Still, Mercury's appearance changes noticeably each evening. On April 9, 90 percent of the planet's disk is illuminated. You'll hardly notice it as less than full. The phase shrinks to 73 percent lit by April 15, and to half-phase April 21. That evening, it shines at magnitude –0.4. By month's end, it will have faded to magnitude 0.7, just a touch brighter than Aldebaran. It will then display a 27-percent-lit crescent.

You can find **Saturn** high in the southeast as soon as the Sun sets. It lies among the background stars of Leo the Lion. At magnitude 0.7, Saturn outshines all of Leo's stars and appears nearly twice as bright as that constellation's luminary, Regulus. On April 6, a gibbous Moon lies 6° south of the planet.

Saturn is a world of rings and moons. The glorious rings currently appear almost edge-on to our line of sight. And the moons, the brightest of which lie near the same plane as the rings, crisscross in front of and behind Saturn just like Jupiter's four bright

Meteor watch



The Lyrid meteor shower peaks this year during the predawn hours of April 22. Observers under dark skies could see up to 20 meteors per hour. *Astronomy*: Roen Kelly

April shower brings spring meteors

Following the typical meteor lull in late winter and early spring, activity picks up during April's second half. The annual Lyrid shower produces the bulk of April's meteors. The shower remains active between April 16 and 25. Astronomers predict the shower will peak in the predawn hours of April 22. With New Moon arriving April 24, conditions could hardly be better.

Lyrid rates vary from year to year, with the peak averaging around 20 meteors per hour under ideal conditions. More often than not, the highest level of activity lasts only a few hours. The radiant lies in the constellation Lyra, near its border with Hercules. Although this area rises before midnight, the best time to view the Lyrids comes in the 2 or 3 hours before dawn. As always, you'll see more meteors if you observe from a dark location.

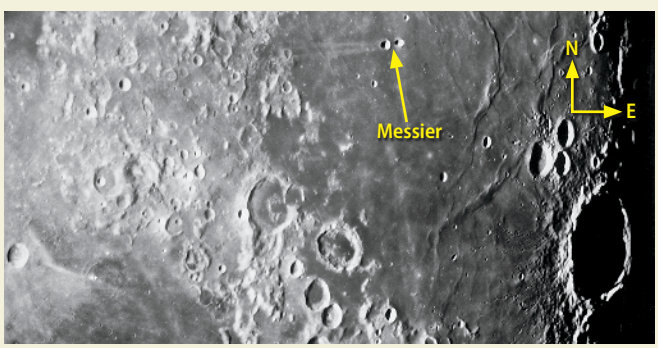
Rising Moon

A striking pair of craters

The vast lava plains of Mare Fecunditatis hold an unusual pair of side-by-side craters. Lunar cartographers named the pair Messier, after the famous 18th-century comet hunter, because two bright streaks reminiscent of a comet's tail spread westward from the pair across the dark mare background. You can locate Messier easily just south of the lunar equator.

As soon as April begins, the Sun lies high enough in the lunar sky to illuminate the double crater. Soon after the 10th, however, sunset looms over Messier, and the rays disappear into shadow. They return again after April 28. If you use an eyepiece that delivers 100x or more, you can see that the craters appear distinctly out-of-round compared with others nearby.

The origin of Messier's slightly diverging white rays puzzled astronomers for centuries because there's nothing else like them. Scientists developed several bizarre and off-base theories to explain Messier and its rays. In 1978, planetary scientists Don Gault and John Wedekind showed that Messier formed when a fast-moving projectile whacked the Moon from the east. The object struck at a grazing angle and skipped once, spraying debris forward. Although a comet nucleus might have done the trick, a rock seems more likely.



The twin craters Messier stand out in Mare Fecunditatis. Look for two bright rays emanating westward from the pair across the darker lava-filled basin. *Consolidated Lunar Atlas*/UA/LPL

At the Ames Vertical Gun Ballistic Range, Gault and Wedekind shot small pellets at different targets at mind-numbing speeds of 15,000 mph. They discovered how the craters and the spray change shape as they adjusted the firing angle. The scientists found they could create a double crater with only one pellet. There was no need to invoke the greater coincidence of a double projectile.

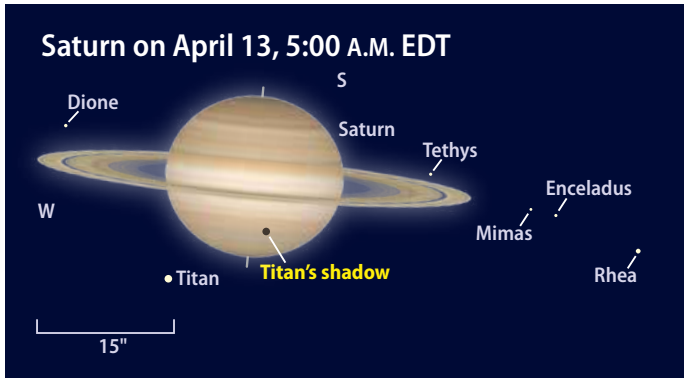
When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Saturn (southwest)	Venus (east)
Saturn (southeast)		Mars (east)
		Jupiter (southeast)
		Uranus (east)

moons. Saturn's axis tilts 27° to its orbital plane, so such a close alignment happens rarely. This year's ring-plane crossing is the first in 14 years. Earth and the Sun both pass through the ring plane late this summer — unfortunately at a time when Saturn lies behind the Sun as seen from Earth.

Saturn's largest moon, Titan, causes two shadow transits in April. Both are visible from North America. During the early morning hours of April 13, watch for Titan's black shadow to begin transiting shortly after 3:22 A.M. EDT (12:22 A.M. PDT). It can take a dozen minutes or so before the shadow becomes noticeable. For those people on the East Coast, Saturn sets before the transit ends at 7:51 A.M. EDT. West Coast observers fare better, seeing the entire event before it concludes at 4:51 A.M. PDT. The second shadow transit of Titan occurs April 29, starting at 2:22 A.M. EDT (11:22 P.M. PDT April 28). The event ends at 7:16 A.M. EDT (4:16 A.M. PDT).

When Titan's orbital motion carries it to Saturn's farside, the moon slides just south of the planet before entering the planet's long shadow. North American observers can view two of these eclipses this month. You'll find Titan entering Saturn's shadow around 5:10 A.M. EDT (2:10 A.M. PDT) April 5 and again at 3:50 A.M. EDT (12:50 A.M. PDT) April 21. In both cases, observers will see Titan fade over approximately 20 minutes.



Titan's shadow sweeps across Saturn before dawn April 13. The black dot takes more than 4 hours to traverse Saturn's cloud tops. *Astronomy*: Rick Johnson

Early April is the best time for viewing another favorite saturnian moon, Iapetus. This two-faced moon has one hemisphere as bright as snow and one as dark as charcoal. The bright side faces Earth when Iapetus lies far west of Saturn, and the dark side points toward Earth when the moon appears far east of the planet. The upshot: Iapetus' brightness changes by a factor of five as it orbits Saturn. The moon shines at its brightest when it reaches greatest western elongation April 2. It then glows at magnitude 10.1.

No other planet rises until well past midnight. The first to appear is **Jupiter**, which leads the pack of three other planets — Neptune, Venus, and Mars — congregating in the morning sky. At magnitude –2.1, Jupiter shines far brighter than any other object in the dim region of sky inhabited by Capricornus. It rises by 5 A.M. local daylight time April 1 and about 90 minutes earlier by April 30.

Jupiter doesn't climb high in the southeast before twilight begins. The low altitude limits the detail visible on the planet's 36"-diameter disk. Don't give up, however; continue following the planet into twilight. When Jupiter's

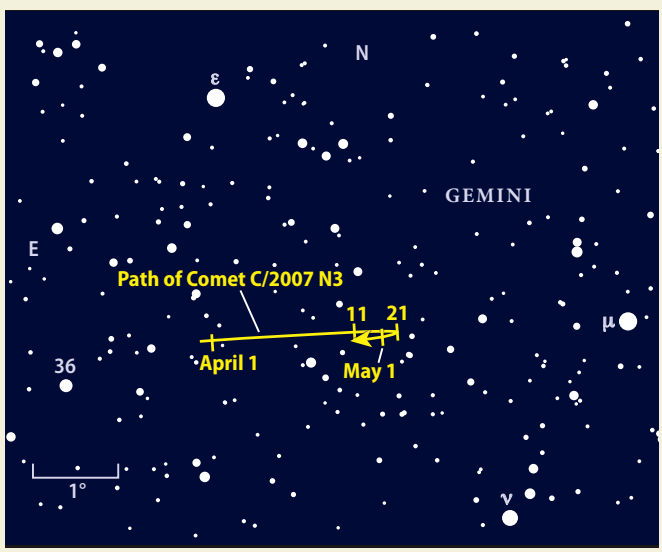
Comet search

Lulin glows near the feet of Gemini

You probably won't need a finder chart to track Comet C/2007 N3 (Lulin) after mid-April because it pretty much comes to a stop. But the comet does fade considerably this month. You'll need moonless, rural skies and a 4-inch scope to see it well.

Lulin lies in western Gemini, not far from the bright star cluster M35. While you're in the area, take a look at this star city and its smaller companion, NGC 2158. In a small scope at low power, NGC 2158 might mimic the comet's appearance. Move up to 150x to probe the structure of both objects. Comet Lulin has faded to 10th magnitude, so it will take patience and averted vision (glancing to the side of the field of view) to detect its short tail of dust and gas.

How can the comet remain in the same sky region, particularly when it orbits the Sun in the opposite direction of Earth? Imagine we're in a car (Earth) traveling southwest from the city center (the Sun), while the comet is another car heading southeast. Whenever we hit an east-west crossroad, we can look east and see the comet car with Gemini's stars behind it. Compared with the buildings (the inner solar system) we're moving apart in different directions, but, relative to the background, the comet stays in the same place. It's the same reason the Moon appears to follow you when you drive.



Comet C/2007 N3 (Lulin) glows at 10th magnitude in late April when you can find it in Gemini just a few degrees from the 3rd-magnitude stars Epsilon (ε) and Mu (μ) Geminorum. *Astronomy*: Rick Johnson

Locating **asteroids**

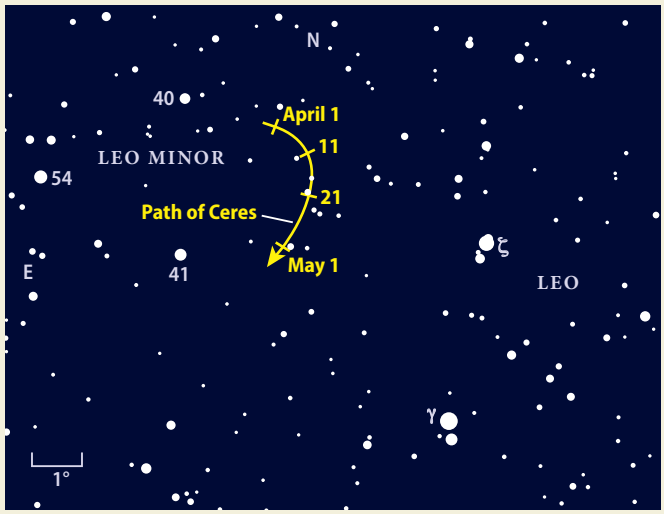
Ceres plies the Lion's den

Leo's Sickle asterism — the chain of stars that arcs northward from the bright blue-white star Regulus — is one of the first patterns beginning stargazers learn. This month, you can use the Sickle to guide you to Ceres, the first asteroid astronomers discovered. Ceres lies a short jump east of the Sickle. Glowing around magnitude 7.5, this main-belt asteroid lies within range of binoculars from the suburbs, but many observers will need a telescope to track it down.

Take advantage of the higher powers at your fingertips and focus first on Gamma (γ) Leonis. At magnifications above 100x, you can see that this golden-orange beacon has a 3.5-magnitude companion sitting a comfortable 5" away.

From Gamma, star-hop to 40 Leo Minoris. Then use the finder chart to identify the star patterns that will lead you to Ceres. The asteroid glows near the same brightness as many of these background stars, which will skew the patterns.

Ceres ranks as the biggest and most massive asteroid. It spans approximately 600 miles and contains more material than all the other asteroids combined.



Asteroid Ceres remains an easy target throughout April as it moves slowly against the background stars of Leo. *Astronomy*: Rick Johnson

yellowish disk appears against a deep-blue sky, the reduced contrast enhances the visibility of some features.

Jupiter's path brings it into the same region as **Neptune**. At magnitude 7.9, Neptune is a binocular object at best. But with Jupiter acting as a luminous guide to the more distant giant planet, Neptune will be easier to find than usual this month. In early April, locate Jupiter in your binoculars, and look for Neptune 5° to the east. By month's end, the more-distant planet lies just 2° east of Jupiter. You'll first see a 5th-magnitude star, Mu (μ) Capricorni. Neptune lies less than 1° above Mu and appears substantially dimmer.

Venus begins April low in the east shortly before sunrise. You'll need a clear and unobstructed horizon to see it April 1, when it lies 5° high 30 minutes before sunrise. Still, it's an impressive observation because the planet will have passed nearly between the Sun and Earth (inferior conjunction) just 5 days earlier.

Venus is able to pierce the twilight because it shines much brighter than any other object in the sky. On the 1st, it gleams at magnitude –4.2. By the 30th, it has brightened considerably, to magnitude –4.7, and appears significantly higher in the predawn sky.

April is an especially good time to view Venus through a telescope. It shows a waxing crescent phase that reverses the waning crescent on display during March. Venus' crescent thickens from 2 percent April 1 to 24 percent April 30. During the same period, Venus' apparent diameter shrinks from 59" to 40".

As impressive as Venus looks any clear morning, it really stands out when a waning crescent Moon passes nearby April 22. The 17-percent-lit crescent of Venus visible through a telescope doubles the Moon's phase. Anyone with a clear sky will enjoy the objects' close proximity, but the real treat awaits observers located west of a line that runs from near Detroit south to El Paso, Texas. For those people, the Moon occults Venus.

As the event begins, the Moon's bright limb covers Venus' dark side. Exact times vary significantly, depending on your geographical location. As a rough guide, the occultation starts after 7 A.M. CDT in the Midwest, where it's already daylight. On the West Coast, the event occurs during twilight (after 5 A.M. PDT), when the pair lies near the eastern horizon. To find the times for your site, go to www.lunar-occultations.com/iota/iotandx.htm.

The Moon occults Venus the morning of April 22 for observers in the western two-thirds of North America. The same thing happened in Europe December 1, when Jupiter lay to the pair's upper right. George Papantinas

The month's final planets prove much harder to see.

Mars hangs low in the eastern sky before dawn all month, although its visibility improves by late April. And at magnitude 1.2, it shines more than 100 times fainter than Venus. Look for the Red Planet 6° south of Venus April 18. On April 14/15, Mars passes 0.5° south of **Uranus**. Unfortunately, for those of us in the Northern Hemisphere, 6th-magnitude Uranus glows too dimly to be seen in the encroaching light of dawn.

Is the Big Bang in trouble?

The cosmologists who explained how our universe came to be now face their greatest challenge: proving exotic fundamental concepts like dark matter and dark energy.

by Daniel Pendick

Galaxies, stars, planets, and ultimately you and I started nearly 14 billion years ago in an unimaginably hot and dense state, before matter and energy as we understand it even existed. The primordial universe expanded and cooled after this cosmic Big Bang. Infinitesimal energy fluctuations, like barely audible overtones dancing on a piano string, expanded to cosmic proportions, imparting structure to the universe. Matter congealed into galaxies; galaxies huddled together to form vast clusters spanning tens of million of light-years.

Roughly 9 billion years after the Big Bang, cosmic expansion sped up. Five billion years later, humans evolved on planet Earth and developed large brains, telescopes, and physics, and used them to create the standard cosmological model. The standard model offers a comprehensive explanation for the origin, evolution, and fate of the universe.

Plenty of evidence exists to support the standard model, most notably the radiation afterglow from the Big Bang that we now observe as the cosmic microwave background (CMB). Maps of the CMB from the Cosmic Background Explorer (COBE) and, more recently, the Wilkinson Microwave Anisotropy Probe (WMAP) confirm several major predictions of Big Bang cosmology.

But the standard model still has a few trouble spots. Key unanswered questions for modern cosmology include the true nature of dark matter — the glue that binds galaxies together — and strange patterns in the CMB that challenge one of the foundations of the standard model, inflation theory.

> "When it comes to dark energy, we know that it exists, but we don't know anything about it."
> — Lawrence Krauss

Also, explaining certain aspects of the standard model has inspired cosmologists to propose some strange ideas — the strangest of all being dark energy.

When observations of distant supernovae revealed that cosmic expansion is accelerating, dark energy offered a ready explanation. But dark energy creates nearly as many problems as it solves. "When it comes to dark energy, we know that it exists, but we don't know anything about it," says Lawrence Krauss, a theoretical physicist and cosmologist at Arizona State University.

WMAP's detailed portrait of the CMB, the supernova observations, and various surveys of the distant universe have advanced cosmology at light-speed. But those discoveries were merely the low-hanging fruit, Krauss says. "We've been so successful that the questions we're asking now are so deep that they may remain unanswerable for some time to come — and maybe forever. We don't understand this model that we have. It's completely inexplicable."

Inflating creation

Inflation theory holds that moments after the Big Bang, the universe passed through a brief period of exponential expansion. The concept of inflation resolved fundamental theoretical prob-

Daniel Pendick *is an associate editor of* Astronomy.

The Big Bang

According to Big Bang cosmology, the universe began in a hot, compact state and has been expanding and cooling for the past 13.73 billion years. With expansion and cooling came formation of large-scale structures like galaxies and galaxy clusters.

Measurements confirm space is expanding in all directions. The farther we look out into the universe, the faster everything is moving away from us. Expanding space stretches, or redshifts, the light from distant galaxies on its way to us. The degree of redshift tells us how far back in cosmic time the light left the galaxy.

Big Bang nucleosynthesis provides more evidence for the standard model. In the first few minutes of expansion, fundamental particles cooled and combined to form atomic nuclei. When astronomers looked in primordial gas clouds between galaxies, they saw just the right kind of atoms in the right proportions.

The hot, dense cosmos began to expand and cool 13.73 billion years ago. *Astronomy*: Roen Kelly

lems for Big Bang cosmology. The initial idea has blossomed into multiple versions that rest on a solid foundation of theoretical physics.

But this still leaves an unresolved question: How do we know inflation really happened? "The idea that there was a period of exponential growth is by far the best explanation we have of the current data," says Gary Hinshaw, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "But the details of inflation, we have very little grasp of."

Hinshaw was a member of the team that designed WMAP and remains head of data analysis for the project. So far, WMAP's portrait of the CMB is completely consistent with inflation.

Cosmologists hope to find harder evidence. Theoretically, inflation generated ripples in space-time called gravitational waves. The waves would have left an imprint on the CMB. The European Space Agency's Planck satellite, slated to launch in 2009, might find the imprint.

But even that might not dispel all doubt, Krauss says. Gravitational-wave imprints would — again — simply be consistent with inflation. Other processes could create the same pattern. "The issue is not whether it is consistent with observations," Krauss explains. "The question is how to falsify it. What could you observe that would be different if inflation did not happen? It is a beautiful, natural explanation of everything we see, but that doesn't mean it's right."

Searching for the dark stuff

Dark matter's gravity enabled microscopic density fluctuations in the primordial universe to coalesce into the vast structures we see today, like galaxies and galaxy clusters. In fact, dark matter's gravitational influence keeps galaxies and galaxy clusters from flying apart.

Most dark matter may exist in the form of exotic particles such as neutralinos — cousins of normal matter predicted by the theory of supersymmetry. Now if only we could find a single iota of the stuff. "It's a wonderful fit to the data, but as yet there's no laboratory detection of a particle," says physicist Tom Shanks of Durham University in England.

Various kinds of detectors are searching for the elusive dark matter particle. Millions of them should be streaming through every square meter of Earth as it orbits the Sun. But so far, nobody has found one, and the evidence for dark matter remains circumstantial.

Some researchers champion an alternative to dark matter called modified gravity theory, which holds that gravity behaves differently on the vast scales of galaxies and galaxy clusters. Essentially, modified gravity theory says it takes less mass to drive celestial motions if they occur over distances of thousands to millions of light-years.

Modified gravity equations account for some of the same observations as dark matter. However, it faces a major hurdle — Albert Einstein's general theory of relativity. Modified gravity doesn't yet explain the universe as comprehensively as general relativity. Perhaps modified gravity awaits its Einstein.

The seeds of structure

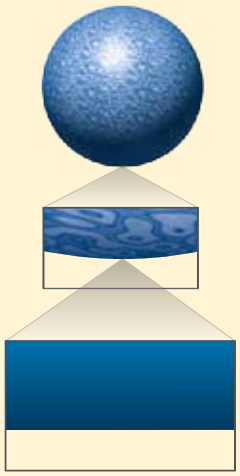
Data mined from the CMB support key aspects of the standard model. Most famously, the CMB contains a snapshot

Inflation

A fraction of a second following the Big Bang, the universe experienced a brief period of hyperexpansion, known as inflation. The cosmos ballooned trillions of times its former dimensions.

Inflation explains the near "flatness" of the universe. It is just dense enough to permit matter to coalesce into structures despite continued cosmic expansion.

For such near-flatness to exist today, the infant universe must have been even closer to perfectly flat. A bit too much matter and energy, and the universe would have collapsed long ago in a Big Crunch. With slightly too little density, it would have expanded rapidly into sparse cosmic fluff with no galaxies or other complex structures.



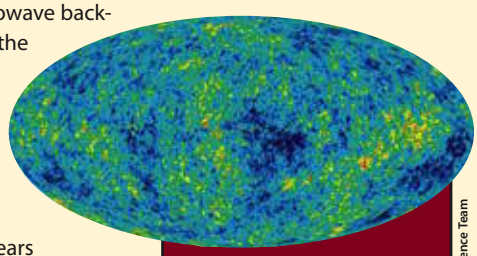
Hyperinflation smoothed out lumps in the early universe, making it "flat."

Astronomy: Roen Kelly

Inflation theory solved the so-called flatness problem. It made the universe precisely flat right after the Big Bang by stretching out any small deviations. As a result, the content of the universe is uniformly distributed (homogeneous) and looks the same no matter what direction you look (isotropic).

The cosmic microwave background

The cosmic microwave background (CMB) is the remnant afterglow of the Big Bang. Hot hydrogen plasma filled the early universe. About 380,000 years after the Big Bang, the plasma cooled enough for its nuclei and electrons to recombine into stable atoms.



Warm (red) and cool (blue) spots in the CMB mark the seeds of cosmic structure.

NASA/WMAP Science Team

Suddenly, photons of light formerly trapped in the plasma burst forth. Today, they form a microwave background glow. Tiny temperature fluctuations in the CMB reflect density variations, or "lumpiness," in the early universe. The first galaxies grew around these primordial "seeds."

The temperatures of warm and cool spots differ by only 1 part in 100,000, which reflects the homogeneous and isotropic universe created by inflation. The warmest spots in the CMB lie about 1° apart in the sky — also predicted by inflation.

Analysis of the CMB confirmed estimates of how much normal matter, dark matter, and dark energy should exist in today's universe. The latest statistics: 4.6 percent normal matter, 23.3 percent dark matter, and 72.1 percent dark energy.

of the seeds of cosmic structure that evolved after inflation. No one could fault British theoretical physicist Stephen Hawking for proclaiming the COBE satellite's first glimpse of the CMB as "the discovery of the century, if not all time."

But nothing is beyond question in the standard model. Since WMAP released its first set of data in 2003, scientists have found patterns in the CMB that seem at odds with the standard model.

Each red or blue speckle in WMAP's mottled portrait of the CMB represents a small fluctuation above or below the average temperature of 2.73 kelvins, or –454.8° Fahrenheit (–270.4° Celsius). The differences in temperature are as minuscule as 1 part in 100,000.

If the cosmos is truly smooth, the size of the fluctuations should be isotropic — uniform no matter which direction in the microwave background an observer looks. However, this may not be so. Some recent studies have identified irregularities, or anisotropies, in the CMB.

In one finding, the fluctuations appear slightly larger in the southern hemisphere of the microwave sky compared with the northern hemisphere. Another study found a peculiar alignment of warm and cool regions that researchers playfully named the "axis of evil."

It remains unclear what causes the anisotropies and what they mean — if anything — for the standard model. Inflation could have produced anisotropies just by random chance. The question is just how likely nature is to produce such irregularities by chance, as opposed to because of some as-yet undiscovered aspect of inflation.

If someone finds a one-in-a-million weirdness in the CMB — highly unlikely to be an accident — it might suggest something is wrong with inflation theory. "The consequences are potentially profound," Hinshaw says. "The large-scale alignments in the CMB might be inconsistent with inflation."

One possible explanation for the anisotropies is that inflation pushed slightly more in one direction than others, creating subtle imbalances in the CMB. But this is speculation right now.

Dark times for dark energy?

In the standard model, dark energy is the intrinsic "vacuum energy" of empty space. And it may truly be a cosmological constant like the one Einstein proposed in his first draft of general relativity. As space expands, the density of dark energy (and its repulsive effect) remains constant, while matter (and its gravitational pull) thins out. The result: cosmic expansion speeds up.

It's possible to calculate the energy of empty space using general relativity and quantum mechanics. The answer is 10^{120} times more energy than astronomers have actually measured. That's the number 1 followed by 120 zeroes, a quantity Krauss dismisses as "ridiculous."

Krauss and other theorists find it unsettling that the universe contains just enough dark energy to have allowed galaxies and other structures to form — and, coincidentally, human observers to exist. If there were a small amount or none at all, the universe would have collapsed in a Big Crunch early in the expansion.

However, if dark energy matched the incredibly large proportion predicted by quantum physics, it would have expanded so rapidly that nothing more than a thin fog of matter and energy would fill the universe today.

Cold dark matter

About a quarter of the universe consists of exotic particles called cold dark matter. Dark matter does not emit light, so it is invisible to telescopes. Particles of dark matter are thought to interact weakly with normal (baryonic) matter, which is composed of protons, neutrons, and electrons.

Dark matter particles move relatively slowly, making them "cold," unlike hot particles, such as photons, that travel at light-speed. Cold dark matter does have mass, so we can infer its presence from its gravitational effects on normal matter and light.

Astronomers mapped the hazy halo of dark matter around this galaxy cluster.

NASA/ESA/M.J. Jee & H. Ford (Johns Hopkins University)

Dark matter forms extended halos around galaxies and clusters of galaxies. Individual galaxies in clusters move so fast that they would fly off into space if not for the binding gravitational pull of dark matter. Light from background objects bends slightly as it passes galaxies. Using this gravitational-lensing effect, astronomers have mapped the distribution of dark matter around galaxies and galaxy clusters.

No one has produced an undisputed observation of a dark matter particle. Many experiments are underway to do so.

Dark energy

In the standard model, dark energy arises from empty space. It's distributed evenly throughout the universe and exerts a repulsive (outward) force. As space expands, dark energy maintains a constant density, while matter thins out.

Dark energy assumed a key role in the standard model after supernova surveys in the late 1990s showed that cosmic expansion is speeding up. Dark energy provided an explanation: As space expands, the total amount of dark energy increases. Meanwhile, matter grows ever more thinly spread, weakening its gravitational pull on the universe. The higher proportion of dark energy causes cosmic expansion to accelerate.

Virtual particles winking into empty space and then annihilating each other may be the source of dark energy.

Astronomy: Roen Kelly

Dark energy's true nature is a mystery. Quantum physics says that virtual particles can wink in and out of existence in a vacuum, perhaps conferring dark energy to empty space. But calculations show this energy should be vastly greater than what we measure: 10^{120} times more, or the number 1 followed by 120 zeroes. The mismatch remains unexplained.

In short, we seem to live in the best of all possible universes. To explain this cosmic coincidence — one that seems to stack the odds in favor of our existence — some scientists invoke the anthropic principle. It says that the universe has the ideal amount of dark energy because we wouldn't be here to measure it if it didn't.

In this view, we live in a multiverse in which any amount of dark energy can exist in multiple drafts of the cosmos. And our universe happens to possess the ideal amount of dark energy. "If the amount of dark energy weren't that much bigger than what we measure, then there wouldn't be galaxies," Krauss summarizes. "And if there weren't galaxies, there wouldn't be stars; and if there weren't stars, there wouldn't be planets; and if there weren't planets, there wouldn't be astronomers."

The anthropic principle's explanation for dark energy has the potential to shake the foundations of all physics, Krauss says. "Physics is supposed to predict why things are and why they have to be that way. This would say they don't have to be that way at all. They just happen to be that way because we're here."

Lost in the Hubble Bubble

Some researchers have proposed to solve the problem by getting rid of dark energy entirely. It's theoretically possible to modify the standard model so that dark energy is not necessary to explain accelerated cosmic expansion.

> "The real universe looks more complex than the idealized model that makes us infer dark energy."
> — Subir Sarkar

For example, Oxford University theoretical physicist Subir Sarkar and other researchers are investigating an alternative — the "Hubble Bubble" hypothesis. It holds that the local universe lies in a region of space with less-than-average density. As such, it would expand at a faster-than-average rate relative to the space outside the bubble. If this is true, then accelerated cosmic expansion may be just a mirage caused by the assumption that the universe is homogeneous and isotropic on all scales.

Critics say the Hubble Bubble hypothesis is an example of stacking up "what ifs" until they add up to the desired answer. "You can contrive models to fit the data without dark energy," Hinshaw says, "but it then becomes a question of what is really plausible." Dark energy, he says, is the most plausible of all known possibilities.

But Sarkar insists it's too soon to dismiss alternatives when confronted with something as bizarre as dark energy. "The real universe looks more complex than the idealized standard model that makes us infer the existence of dark energy," he says. "And it is presumptuous to imagine that cosmology is basically sorted out. I think we have just started."

Why is 40 percent of the universe's normal matter missing? Find out at www.Astronomy.com/toc.

Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

How stars orbit inside clusters

Q: How do stars move inside a globular cluster? Do they orbit a black hole, like the stars in the Milky Way Galaxy? — **James Saicheck,** Banning, California

A: The stars in most globular clusters orbit the group's center of mass. In certain clusters, the stars may orbit black holes.

Globular clusters are spherical assemblages containing up to a million stars bound to each other by gravity. The clusters' stars travel through the universe as a self-contained unit.

If you could watch a time-lapse movie of a globular cluster spanning millions of years of its stellar motions, you'd see something reminiscent of a swarm of bees. Each individual star follows a unique orbit around the cluster's center of mass. Some of the stars trace nearly circular orbits that keep them at the same distance from the center. Other stars follow more elliptical orbits that carry them close to the cluster's center.

Some globular clusters appear to harbor central black holes, according to recent observational evidence. Astronomers can't directly image the black holes. Instead, they track stars near the center and see how the black hole's gravity speeds up their orbits.

One globular cluster thought to enclose a black hole is M31 G1. Its myriad stars may conceal a black hole containing an estimated 20,000 times the Sun's mass. — **William Harris,** McMaster University, Hamilton, Ontario

M31 G1 is a globular cluster in the Andromeda Galaxy. Observations suggest its stars orbit a central black hole containing 20,000 times the Sun's mass. Located 130,000 light-years from Andromeda's central nucleus, M31 G1 is the brightest globular cluster in the Local Group of galaxies. NASA/Michael Rich (UCLA)

METEORITES FOR SALE

Q: Is there a simple way for amateur collectors to determine if meteorites for sale are authentic?

— **Joseph Rusz,** Oak Hill, Virginia

A: No simple, on-the-spot test can tell you if a meteorite is authentic. To stack the odds in your favor, educate yourself about meteorites and buy from a reputable dealer who offers an ironclad return policy.

When buying meteorites, it's always best to examine the specimen firsthand. Learn the basic characteristics that will allow you to distinguish genuine meteorites from "meteor-wrongs." For example, most meteorites contain iron and will attract a strong magnet.

If you are shopping online, buy from a well-known dealer. Be careful when buying meteorite samples in online auctions using eBay. Make sure you can return the specimen and get a refund if you have any doubts about its authenticity.

Also, pay attention to the quality and professionalism of the web site, which can tell you a lot about the dealer. Does the site provide complete contact information, including a mailing address and telephone number?

The best meteorite web sites include a good deal of educational material to aid the customer. One example is the Meteorite Market (meteoritemarket.com), which is loaded with useful information.

— **Raymond Shubinski,** Contributing Editor

THE HOLE TRUTH

Q: Can a black hole swallow an entire galaxy? — **Jordanna Haagen,** Abbotsford, British Columbia

A: Theoretical research suggests a black hole could never grow big enough to swallow a galaxy. This is because black holes limit their own growth through a dynamic feedback process. As the black hole consumes stars and gas, it releases radiation. At some

point, the radiation's outward pressure cuts off the black hole from its own food supply and growth ceases.

Most large galaxies seem to have so-called supermassive black holes at their centers, containing millions to billions of times the Sun's mass. The galaxy M87, for example, harbors a black hole weighing some 3 billion solar masses.

Yet even supermassive black holes don't have enough "pull" to consume a galaxy. Their strongest influence reaches only to around 10 light-years, whereas most galaxies extend at least 1,000 times that scale. **— Eliot Quataert,** Theoretical Astrophysics Center, University of California at Berkeley

LOOKING SHARP

Q: Why do images of stars often show four spikes radiating from the stars' centers?

— Len and Carolynn Strilchuk, Vernon, British Columbia

A: Those spikes are caused by the diffraction of light around the supports for a reflecting telescope's secondary mirror.

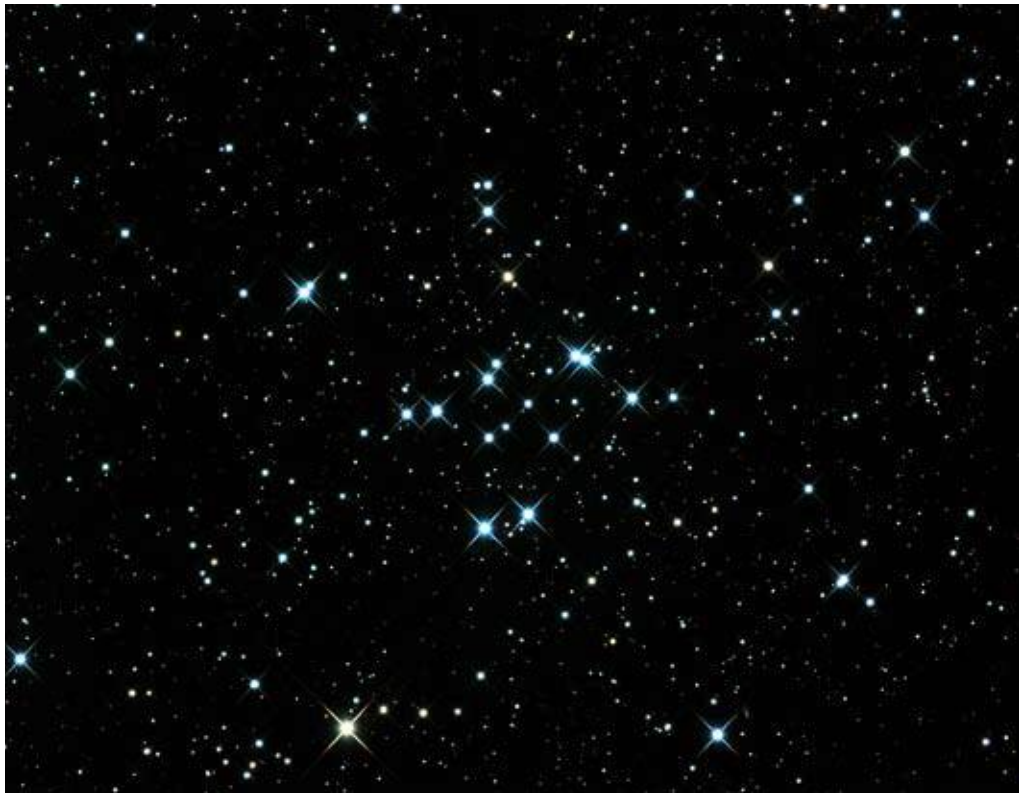
The support, commonly called a spider or spider-vane assembly, consists of three or four rigid vanes that hold the secondary mirror stationary in the telescope tube. The secondary mirror is the one that deflects light from the primary collecting mirror to the eyepiece.

Light waves interact with the vanes and create the spikes. The features are usually not visible to the naked eye, but a camera easily captures them during long-exposure shots.

Some astroimagers deliberately introduce spikes because they like the "Star of Bethlehem" effect they create around bright stars. One way to introduce a spike effect is by attaching two pieces of string across the front of the telescope to form cross hairs. Usually the strings run 90 degrees to each other, but I've seen some wacky combinations, including some using more than two strings.

Certain types of telescopes do not produce diffraction spikes. These include refractors and Schmidt-Cassegrains. Neither type has a secondary mirror mounted on vanes. **— Michael E. Bakich,** Senior Editor

How do X-ray telescopes work? Find out at www.Astronomy.com/toc.



Diffraction spikes project from the stars in this image of the open cluster M34 (NGC 1039). Some astroimagers deliberately include such spikes in their celestial portraits. Anthony Ayiomamitis

HIGH-TECH IMAGING

Q: Would it be possible for an amateur astronomer to combine multiple telescopes into a long-baseline interferometer?

— Philip de Louralle, Los Gatos, California

A: Long-baseline interferometry allows astronomers to combine light from two or more telescopes and thus exceed the resolution of the individual instruments. The technique boosts our ability to see fine detail. **However, imaging stars with long-baseline interferometry is beyond the capability of most amateur observers.**

Interferometers pipe light from multiple telescopes to an instrument called a correlator/combiner. The light waves mix, generating an "interference" pattern of alternating light and dark fringes. Light fringes (peaks) show where wavelengths combine; dark fringes (valleys) indicate where wavelengths subtract.

By measuring the peaks and valleys and their positions relative to each other, it's possible to image the actual disks of stars. My colleagues and I recently used the CHARA interferometer at Mount Wilson Observatory in California to determine that the rapidly rotating star Altair is 22 percent wider than it is tall.

For long-baseline interferometry in visible light, you have to be able to measure the interference pattern and distance between the telescopes to an accuracy of less than a millionth of a meter, or about 1/100 of the width of a human hair. This demands specialized and expensive scientific equipment.

However, an amateur astronomer can witness the interference effect in a small telescope using a technique called aperture masking. Make a cover, or mask, for the front of your telescope. Cut two small holes at different locations.

Now, observe a bright star at high magnification (over 100x). You should see a bright spot crossed by blurry fringes. Starlight from each hole takes a slightly different path to your eye and combines, creating interference fringes. **— John D. Monnier,** University of Michigan, Ann Arbor

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Find your way through the spring sky

Warm weather and giant constellations beckon beginning observers.

by Michael E. Bakich

Ah, spring. Finally, it's warm enough for even thin-blooded observers (like me) to break out their binoculars and telescopes. If you're new to astronomy, however, you'll want to become familiar with the constellations and bright stars that populate this season's night sky before looking through the eyepiece. Then, when you read that a sky treat is in Boötes or near Regulus, you'll already have a frame of reference.

High in the northeast, the sky's most recognizable star pattern — the Big Dipper — is easy to spot after sunset. The Dipper is part of the third-largest constellation, **Ursa Major** the Great Bear, but the other stars are all faint, so concentrating on the Big Dipper is the way to start.

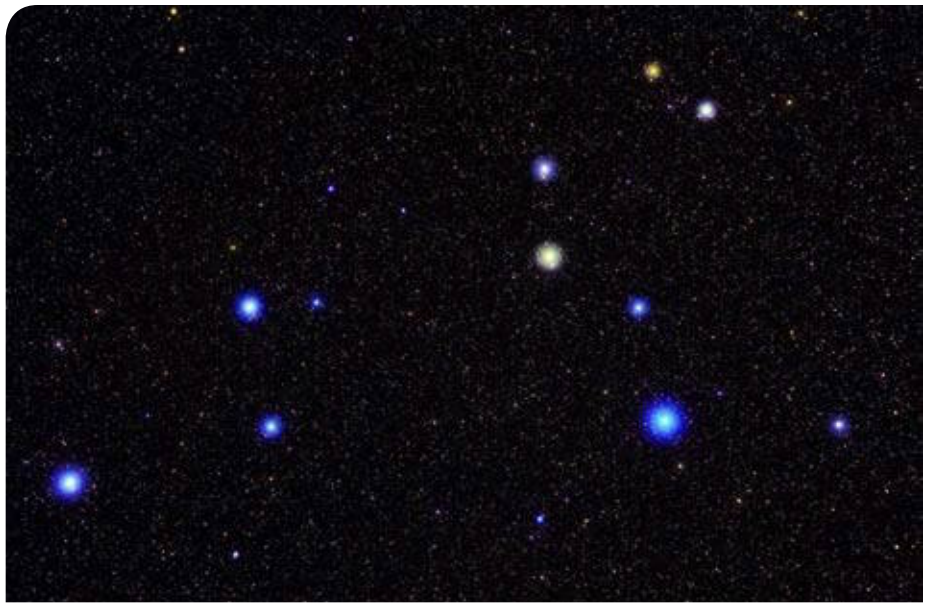
Find the bend of the Dipper's handle. Sharp-eyed observers can tell that two stars occupy this space. Arabian astronomers 10 centuries ago called this pair the Horse and Rider.

The brighter of the two is **Mizar** (Zeta [ζ] Ursae Majoris). It shines at magnitude 2.2. Alcor (80 Ursae Majoris), which sits 0.2° east-northeast of Mizar, glows at magnitude 4. This pair is an optical double, as in optical illusion. Mizar lies 78.2 light-years away, while Alcor sits 81.2 light-years distant.

Because the Big Dipper is so easy to find, amateur astronomers use it to help them locate lots of constellations and stars in the spring sky. For example, use the Pointer Stars, Dubhe and Merak (Alpha [α] and Beta [β] Ursae Majoris), to find perhaps the most famous single star in the sky: **Polaris**, the North Star (Alpha Ursae Minoris). Draw a line from Beta through Alpha Ursae Majoris, and extend that line about 5 times the distance between those two stars.

Polaris, which lies roughly 430 light-years from Earth, marks the end of the Little Dipper's handle. Alternatively, it's the brightest star in **Ursa Minor** the Little Bear, and it marks the tip of the Bear's tail. Unlike the Big Dipper, however, most of the other six stars of the Little Dipper are faint. You'll need a dark location to see them all.

Head back to the Big Dipper, and locate its handle. Follow beyond the curve of the handle to two brilliant stars: **Arcturus** (Alpha Boötis) and **Spica** (Alpha Virginis). These two luminaries illustrate some of the color differences between stars.



Leo the Lion contains the bright star Regulus (Alpha [α] Leonis). It sits at the base of a sickle-shaped figure that marks the Lion's head and mane. The star Denebola (Beta [β] Leonis) marks Leo's tail.

Arcturus appears copper-colored or orange, while Spica is bright blue. Stars have different colors because nuclear reactions in their cores heat their surfaces to different temperatures. Arcturus is a spectral class K giant star with a relatively cool surface temperature of 4300 kelvins (7300° Fahrenheit).

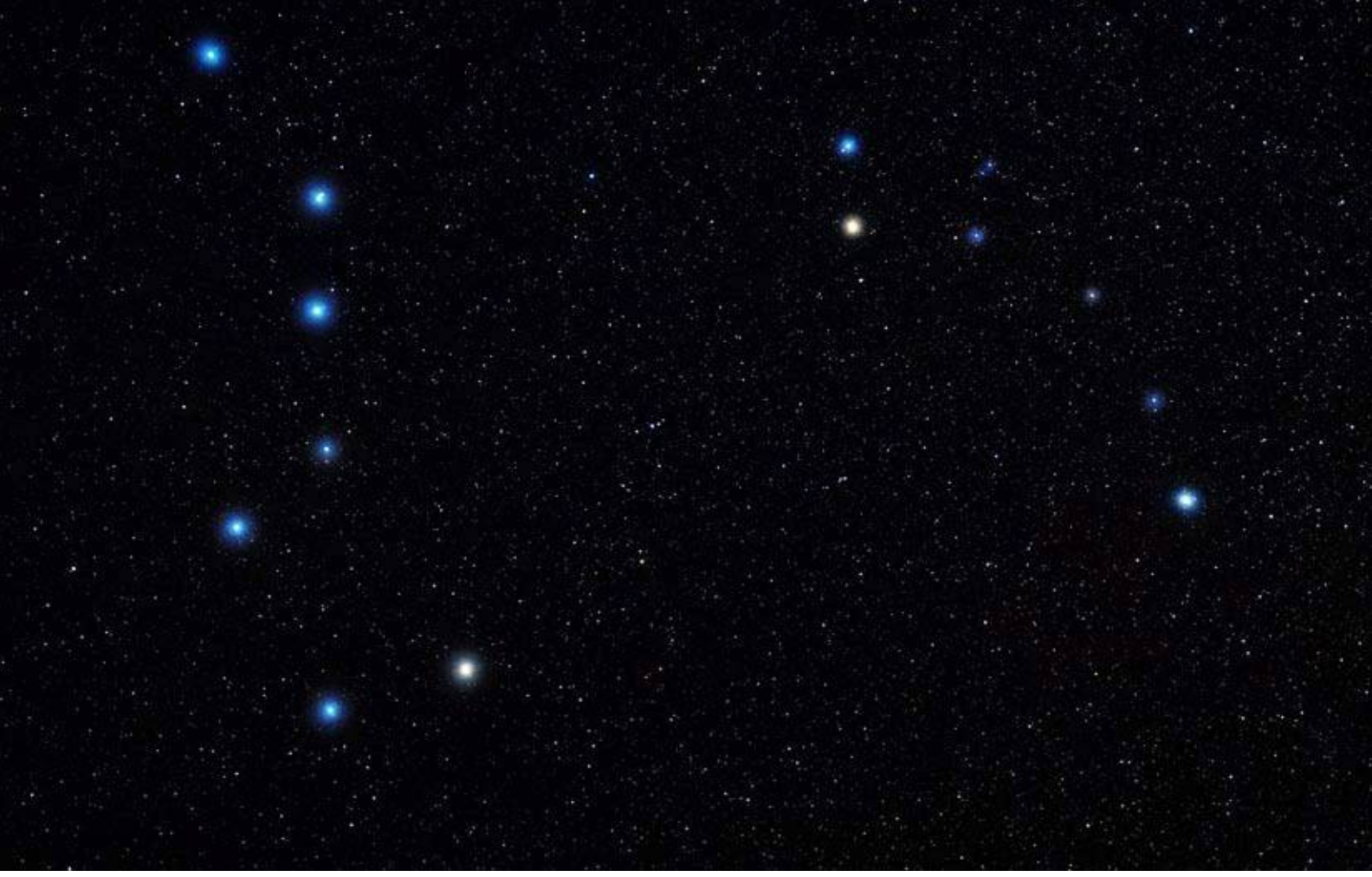
Spica also is a giant, but its spectral class (B1) puts it among the hottest of stars. Its surface burns at 20,000 K (35,500° F). For comparison, the Sun lies in the middle of the temperature range. On its surface, a thermometer would read 6000 K (10,300° F).

Arcturus lies in the constellation **Boötes** the Herdsman some 37 light-years away. The star's name comes from a combination of terms that means "the

Go to the map

Use the star map in the center foldout section of the magazine with this story. **Bold words** are objects you'll find on the map.

Michael E. Bakich *is a senior editor of* Astronomy. *The first constellations he learned, many years ago, were those in the spring sky.*



Ursa Major and Ursa Minor cover a lot of the far-northern sky. The brightest parts of these constellations are the Big and Little Dippers. All images: Bill and Sally Fletcher

Bear's guard," which signifies its position near Ursa Major the Great Bear. The main part of Boötes looks like a thin kite or an ice-cream cone.

Spica sits 260 light-years away in the southern reaches of **Virgo** the Maiden. This sprawling star group ranks second in size among the 88 constellations.

Go back to the Big Dipper. To find our next constellation, poke a hole in the Dipper's bowl, let all the water run out, and wait for a loud roar. Mythologically, that's what you'll hear because the water fell on the back of **Leo** the Lion.

Leo's main figure has two parts: A backward question mark and a triangle. The question mark, or sickle-shaped figure, represents the front of the Lion. Dotting the question mark with a distinctive blue-white color is magnitude 1.3 **Regulus** (Alpha Leonis). Regulus lies 77 light-years from Earth.

East of the sickle, a right triangle marks the Lion's back and tail. The star farthest east of Regulus is **Denebola** (Beta Leonis). It lies 36 light-years away, about the same as Arcturus. Although Denebola carries the "Beta" label, usually signifying the second-brightest star in Leo, Algieba (Gamma [γ] Leonis) slightly outshines it. Algieba is a spectacular orange and yellow double star 126 light-years distant that you'll have no difficulty splitting with a 3-inch telescope.

Some 20° west of Leo's sickle lies one of the sky's faintest constellations, Cancer the Crab. I identify this poor star pattern only so you can point binoculars toward its center. There you'll find **M44**, the fabulous Beehive Cluster. Through 10x50 binoculars most observers can count three dozen stars. The Beehive Cluster lies at a distance of about 580 light-years.

Corvus the Crow is a small constellation shaped like a crooked box. Its bright stars and distinctive pattern make it easy to find.

Below Virgo sits the small constellation **Corvus** the Crow. Its four moderately bright main stars and "crooked box" shape make it easy to find. There's another way to be sure you're looking at Corvus: See if its top two stars point upward to Spica.

If you own a telescope, sometime after you're comfortable locating Corvus, look 5.5° north-northeast of Delta (δ) Corvi for **M104**, also known as the Sombrero Galaxy. M104 is one of the sky's brightest galaxies, shining at 8th magnitude at a distance of some 50 million light-years. Use an eyepiece that magnifies about 100 times, and you easily will identify the "Mexican hat" shape of this star system.

Spring is an ideal time to start learning the sky. Many of the constellations are large, and helpful indicators like the Big Dipper lead you to the brightest stars. Before you know it, summer will dawn. Then, head back to *Astronomy*'s July 2008 issue and read "Find your way through the summer sky."

Chris Schur captures the universe

Detailed galaxy shots, Milky Way panoramas, and gleaming star clusters showcase this skyshooter's best work.

Text and images by Chris Schur

Chris Schur uses a homemade 12-inch f/5 reflector to capture celestial images at his observatory in Payson, Arizona.

Early in life, I fell in love with the sky. Setting up my telescope at night was something I couldn't wait to do. Even as a child, I set my sights on capturing on film the spectacular celestial objects I viewed by eye.

Being born in cloudy Detroit and raised in nearby Milford, Michigan, I had few opportunities for visual observing or astrophotography. At age 20, I moved to Arizona seeking clear skies and hoping to meet other astrophotographers. I soon joined the Phoenix astronomy club. Since then, I've shared my work with lots of amateur astronomers.

Chris Schur *is a frequent contributor of high-quality astroimages to* Astronomy.

Personal evolution

Until about 1990, I recorded photographs on gas-hypersensitized film. The thousands of hours spent perfecting techniques with this medium produced hundreds of articles in books, magazines, and, later, on the Internet.

During that period, my focus was on deep-sky photography. My specialty was the Milky Way and comets. For these photos, I used several Schmidt cameras.

During the following 15 years, I made a slow transition to digital imaging. At first, I used film scanners to digitize negatives and slides. Then, I began direct charge-coupled device (CCD) imaging of deep-sky objects, recording the raw data directly onto a computer. My transition from film to CCD images was easier because many of the same techniques used for digitized film images apply.

I feel like a golfer who owns a house next to the fairway. My "golf course" is the sky, though, and I'm lucky enough to have two observatories. It's an astroimager's dream. One observatory at my primary residence in Payson, Arizona, houses a 12.5-inch f/5 homemade Newtonian reflector. My other facility sits

Reflection nebula M78 in Orion shines mainly bluish because light from stars embedded in and near the nebulosity reflects off the gas and scatters throughout the cloud.

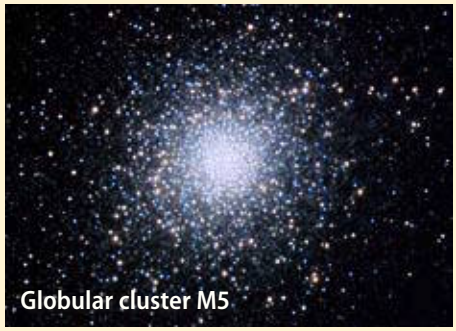
Bode's Galaxy (M81) in Ursa Major has a bright core and subtle spiral arms. To capture both requires Schur to stack multiple exposures and use tested post-processing techniques.

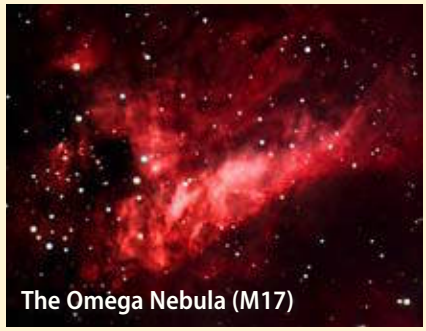
The Pinwheel Galaxy (M33) in Triangulum shows reddish nebulae along its arms. Schur pioneered a technique to reveal such regions in galaxies.

The Running Man Nebula (NGC 1973/5/7) in Orion represents a combination object: Red emission nebulosity winds through a predominantly blue reflection nebula. This LRGB shot required exposures of 80, 20, 20, and 40 minutes, respectively, through the author's 12.5-inch f/5 Newtonian reflector.

Thumbnail image gallery

Astrophotographer Chris Schur has photographed hundreds of deep-sky objects through his 12.5-inch Newtonian reflector. This small gallery shows some of the objects he's targeted recently.


Globular cluster M5


The Omega Nebula (M17)

Supernova remnant IC 443

The Whale Galaxy (NGC 4631)

The Antennae Galaxies (NGC 4038–9)

The Whirlpool Galaxy (M51)

The Blackeye Galaxy (M64)

The Dumbbell Nebula (M27)

The Cocoon Nebula (IC 5146)

The Crab Nebula (M1)

NGC 4485 (top) and NGC 4490

atop the Colorado Plateau in the town of Happy Jack, about an hour's drive north of Payson. I set up that observatory for wide-field imaging under the site's extremely dark skies. Sky conditions are world-class. We're only a few miles down the road from the Discovery Channel Telescope, currently under construction.

My favorite targets

During the past decade, my driving force has been to take long-exposure color CCD images of relatively unknown deep-sky objects. Many of these targets, such as planetary nebula Jones 1 (PK 104–29.1) in Pegasus, have astonishing color variations. Some faint galaxies, such as the dwarf irregular IC 1613 or the irregular Wolf-Lundmark-Melotte (WLM), both in Cetus, show beautiful blue and gold stars along with hydrogen regions, which display shades of red.

Although some amateurs had taken exposures of galaxies through Hydrogen-alpha (Hα) filters, combining the shots with normal color (RGB) images had not proved successful. I spent several years working out how to enhance the beautiful hydrogen clouds that dominate the arms of many bright spiral galaxies. Numerous astroimagers have adopted these techniques. They have found, as I did, that galaxies contain details not previously revealed in amateur images.

Perhaps the most spectacular example in the northern sky is the Pinwheel Galaxy (M33). Normal long-exposure RGB images of this galaxy through large telescopes reveal dozens of faint reddish

This Winter Milky Way image shows what Chris Schur's camera can record when it's attached to, but not shooting through, a telescope. The lens' wide field captured the constellations Orion, Taurus, and Auriga, along with thousands of stars and reddish wisps of nebulosity.

The California Nebula (NGC 1499) in Perseus is an emission nebula that glows in an intense shade of red. The author's image shows none of the false salmon hue inherent in early digital deep-sky photographs. This deep-sky object stretches nearly 2.5° and lies 1,000 light-years from Earth.

Emission nebula NGC 6188 in Ara is an object that climbs no more than 5° above the author's southern horizon. The quality of this image shows not only how dark the sky is at his observatory in Happy Jack, Arizona, but also how steady the air is above the site.

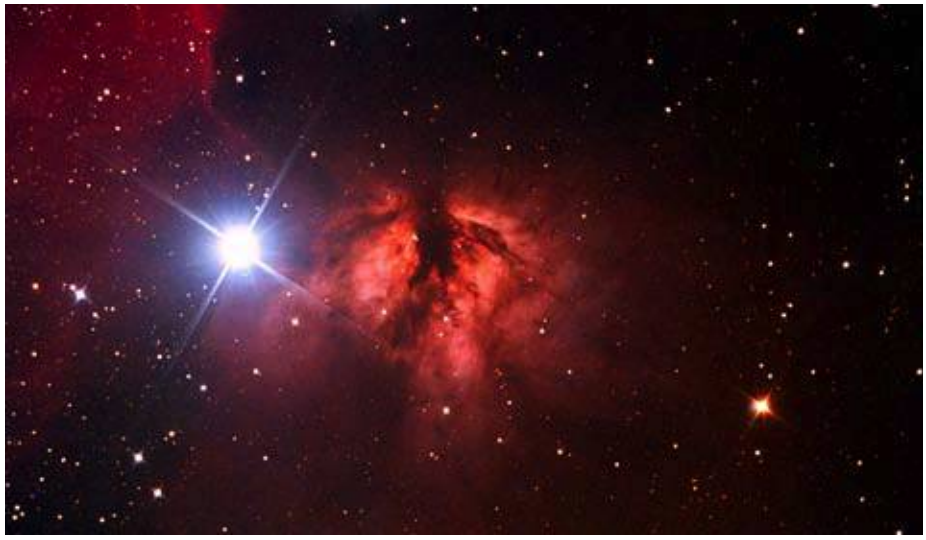
hydrogen clouds across the galaxy's face. But by adding to this image several additional hours of Hα data, the galaxy takes on a more detailed appearance unlike anything amateurs had done before.

With great pleasure, I shared these techniques with other astrophotographers at the 2007 Advanced Imaging Conference (AIC) in San Jose, California. Now they, too, can reveal unseen layers of detail in galaxies.

At our observatory in northern Arizona, I recently replaced my Schmidt camera setup. I now use a digital single-lens reflex camera (DSLR) connected to small, high-quality refractors with state-of-the-art optical tube assemblies. These scopes sit on precision mounts.

The images I produce with a DSLR, a camera that I had modified for extended red response, are every bit as good as those from much more costly CCD camera systems. My primary interest is to use

The North America Nebula (NGC 7000) in Cygnus, which really looks like its namesake, is a bright object, so it doesn't take hours of exposure. The problem with NGC 7000 is its size — more than 2° across. Because it's so big, the author used a camera/telescope combination that produces a wide field of view. The fainter Pelican Nebula (IC 5070) lies to NGC 7000's lower right.



The Flame Nebula (NGC 2024) in Orion usually appears at a smaller scale with the nearby Horsehead Nebula (B33). Here, Chris Schur chose to concentrate on the wispy nebulosity of the Flame.

wide-field imaging to record the numerous emission and reflection nebulae along the Milky Way.

I'll describe how good the northern Arizona site is with an example. Recently, I created a detailed image of NGC 6188, a nebulous region in Ara, which climbs no more than 5° above the horizon at this location. Most observers consider this a Southern Hemisphere object.

The image reveals the heart shape of NGC 6188, the bipolar nebula NGC 6164–5, and five open star clusters. I spend as much time as I can imaging at this site because nearly everything I photograph shows details invisible in images from less favorable sites.

Photographic techniques

I place special emphasis on accurate color reproduction of deep-sky objects. Early on, I discovered that many astroimagers were producing an impossibly wide range of colors. I decided to nail down more accurately the techniques of color balancing. I also wanted to understand and correct one issue with true-color LRGB images: an overall salmon hue. It was quite a battle to convince most astroimagers that the incorrect salmon-pink coloration — usually the result of combining a bright luminance image with RGB data — could be understood mathematically.

At the 2006 AIC, I introduced a simple *Photoshop* technique that corrected this color imbalance. Since then, most new nebula images in magazines and on the Internet have had far more accurate color.

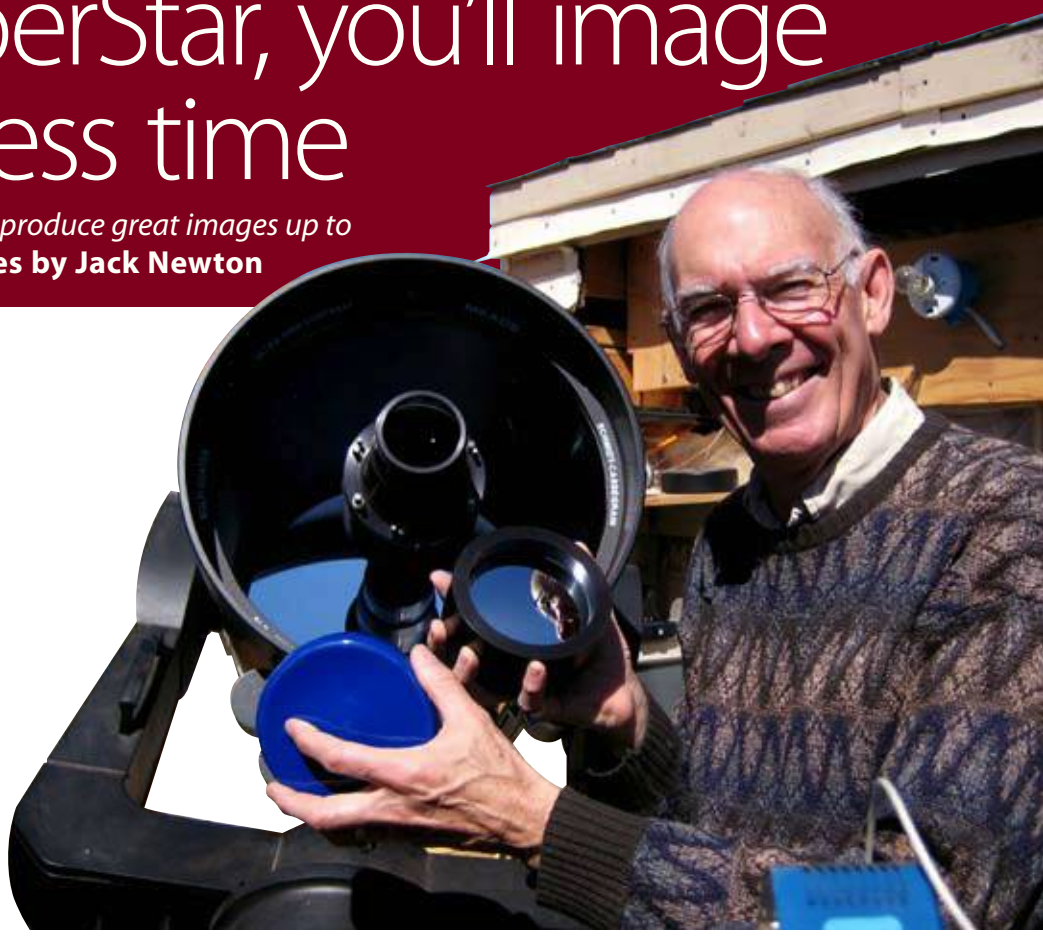
What's next?

I look forward to pushing the envelope with Hα-enhanced galaxy imaging. Dozens of large galaxies, which in the past have shown only hints of pink hydrogen clouds, will be my targets. My wide-field imaging plans include a next generation of robotic cameras. I'll also continue to pursue DSLR imaging with small scopes at Happy Jack. So, as I continue swinging on my celestial golf course, look for more articles, more talks, and, of course, more images in *Astronomy*.

Equipment review

With HyperStar, you'll image more in less time

After a quick alteration, you can produce great images up to 30 times faster. **text and images by Jack Newton**



The author stands near his HyperStar-converted 14-inch Meade Schmidt-Cassegrain telescope.

For years I bought bigger and bigger telescopes so I could get higher magnifications and brighter images. Unfortunately, the trade-offs were bloated stars and tougher guiding. Not anymore. The HyperStar lens system, manufactured by Tucson-based Starizona, allows me to transform narrow-aperture telescopes so they gather light like much bigger instruments.

Lightning fast

With an f/2 focal ratio, the HyperStar lens allows me to take exposures up to 31 times faster than through a standard Schmidt-Cassegrain telescope (SCT) at f/10. A 60-second exposure with the HyperStar at f/2 equals a 30.9-minute exposure at f/10. This makes it simple to take advantage of sky conditions, even when they're short-lived.

I have recently been using Canon digital SLR cameras for color astroimaging. I often couple them with a 4-inch f/4.1 astrograph for wide-field shots. The Canons respond well at fast f-ratios, and that shortens exposure times and results in better images. With the excellent transparency I enjoy by living at Arizona Sky Village, I wanted to acquire a larger-aperture, fast-focal-ratio instrument. The HyperStar lens system was the answer.

Easy to install and use

I was pleased to find that I could transform a Meade or Celestron 8-, 10-, or 14-inch SCT easily into a wide-field f/2 system. Even older models can accept this alteration. What's more, Starizona designed the HyperStar's field flattener to deliver a flat field with no coma.

I love the fact that the HyperStar is threaded for 2" filters. This is perfect for light-pollution control. The conversion from f/10 to f/2 is straightforward. First, remove the three restraining screws that connect the secondary mirror to the corrector plate. Then lift the secondary mirror off its mounting ring, and replace it with the HyperStar. The whole conversion takes about 5 minutes.

Mounting the HyperStar lens system to a Schmidt-Cassegrain telescope takes minutes.

You collimate HyperStar with three push/pull adjustment screws. Because HyperStar increases the weight at the front of the telescope, the manufacturer

— *Continued on page 65*

Specifications

Starizona HyperStar

Focal ratio: f/2.0
Largest usable CCD chip: 27mm (diagonal); up to 42mm is possible on some models with some vignetting
Size: Varies by telescope — up to 6.6 by 4.1 inches (168mm by 104mm)
Weight: Varies by telescope — up to 3.5 pounds (1.6 kg)
Features: Fully multicoated optics, black anodized finish, independent camera rotation
Includes: Secondary mirror holder and counterweight
Price: $595 to $1,295

This composite image of the Horsehead Nebula (B33) and the Flame Nebula (NGC 2024) illustrates how quickly HyperStar produces images. This picture required only 37 minutes of exposure. Also note the wide brightness range captured. The bright star Zeta (ζ) Orionis shines at magnitude 2.0.

The Seagull Nebula (IC 2177) in Monoceros reveals great detail in full color after only 60 minutes total exposure with HyperStar.

The Andromeda Galaxy (M31) is a treasure in the autumn sky. Capturing detail in its outer spiral arms without burning in the core, however, can prove difficult. This image required only 60 minutes of exposure.

The Rosette Nebula (NGC 2237–9) in Monoceros combines a star cluster with emission nebulosity. Through HyperStar, the author captured this image with 36 minutes of exposure.

Perhaps the sky's greatest nebula is the Orion Nebula (M42), a showpiece of the winter sky. This image required 25 minutes of exposure.

A 1-minute exposure of the Pleiades star cluster (M45) surprised the author because behind the brilliant stars and nebulous glow, he captured more than 50 faint galaxies. This 30-minute exposure shows many more. Here, we've zoomed into a portion of it and circled the galaxies.

The Lagoon Nebula (M8) in Sagittarius is a colossal cloud of glowing hydrogen crossed by a dark lane. This 20-minute exposure captures the red color of the Lagoon and its surrounding nebulosity.

Recording the coma and denser pseudonucleus of Comet 17P/Holmes against the background stars took mere seconds with HyperStar.

With a Canon digital SLR camera mounted to a HyperStar-ready telescope, the author is equipped for one-shot color astrophotography.

Meade's Deep Sky Imager PRO III camera mounts easily on the HyperStar. This is just one of the many CCD and digital cameras the HyperStar lens system will accept.

— *Continued from page 62*

provides a threaded counterweight to screw onto the back. The counterweight replaces the star diagonal and eyepiece.

A flexible system

The star images I'm producing with the HyperStar lens are amazing. With my 14-inch Meade SCT and a Canon digital SLR camera set to ISO 1600, I took a 1-minute exposure of the Pleiades star cluster (M45). When I studied the image, I counted more than 50 galaxies buried behind the brilliant stars.

Over many years, I have used a variety of cameras from several manufacturers. Each instrument requires an adapter to fit the critical focal length of the HyperStar lens system.

Various cameras exhibit differing degrees of vignetting (which cuts off the field of view's edges) with HyperStar. Canon's full 35mm frame 5D has substantial vignetting caused by its CCD chip's deep recess. By contrast, Starlight Express mounted the chip at the front of the camera, resulting in no vignetting.

With a focal ratio of f/2, HyperStar offers the additional advantage of requiring no guiding up to exposures of 1 minute or so. For longer exposures with my 14-inch Meade SCT, I use a Meade DSI coupled to a 300mm lens to auto-guide.

My favorite digital SLR is a "cold" Canon XT. The company Central DS (www.centralds.net) modifies Canon XT and 40D models in its South Korea factory. Central DS retrofits these models with a cold chamber that surrounds the CMOS chip and cools it to around the freezing point of water. This is desirable because each 6° reduction in temperature cuts the thermal noise (which shows up as imperfections in the image) in half. The modification necessary to produce this true cold camera also includes a Peltier cooler. A side-mounted copper heatsink pulls the heat from the camera.

Also, a new expanded-frequency infrared (IR) blocking filter helps capture deeper red and Hydrogen-alpha frequencies if you're imaging the Sun. Central DS fits the IR-blocking filter with a heater to remove frost should the CMOS chip's temperature drop below the dew point.

In my opinion, the modified Canon camera available from Central DS used in combination with HyperStar is an unbeatable combination. The modified Canon D40 color images are dramatically better than any I have produced. It performs with so little noise that images don't require a dark frame. If you're a serious astroimager who wants maximum image capture in minimum time, check out the HyperStar.

Jack Newton *is a world-renowned Canadian astroimager who spends half the year at Arizona Sky Village in Portal, Arizona.*

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Find more of Jack Newton's celestial images at www.Astronomy.com/toc.

Observing Basics

by Glenn Chaple

A swarm of stars

Discover why the Beehive Cluster has been a popular sky target since ancient times.

One of the joys of being a novice backyard astronomer is the exhilaration that comes with each discovery. To illustrate the point, let me take you back to an early spring evening in 1964. The Beatles' "British Invasion" of America had just begun, and I trudged outside toting a little 60mm f/12 Gilbert reflecting telescope, the refrains of "I Want To Hold Your Hand" running through my head.

Being an astronomical "rookie," I knew nothing about the early spring constellations. Nevertheless, as my night vision kicked in, I spotted a fuzzy patch of light in a rather barren expanse of sky. It was midway between a pair of bright stars and a large star pattern that formed a backward question mark.

The Beehive Cluster is a stellar gathering 40 light-years across and some 577 light-years away. From that distance, our Sun would be faintly visible in small telescopes as an 11th-magnitude speck. Various sources put the cluster's age at about 700 million years.

Tom Bash and John Fox/Adam Block/NOAO/AURA/NSF

After centering the mystery object in a long metal tube that served as the scope's finder, I peered into the 80x eyepiece. Seeing nothing, I began a methodical sweep. Suddenly, a brilliant swarm of stars popped into view. The sight was absolutely stunning!

At school the next day, I did a little detective work to identify this dazzling cluster. As I glanced over some star charts, I found one that showed two bright stars (Pollux and Castor in Gemini) and a backward question mark (the "sickle" of Leo) bracketing a rather star-poor area (the constellation Cancer). Imagine my excitement when I saw, plotted in the exact location where I had seen it the night before, my mystery object. I had discovered M44, the Beehive Cluster.

Ancient peoples knew the Beehive as the *Praesepe* (Latin for "manger"). Around 260 B.C., the Greek poet Aratos referred to it as the "Little Mist." Its invisibility on an otherwise clear moonless night was considered a precursor of rain — not a bad meteorological forecasting tool, as the light haze that frequently precedes inclement weather will often veil the Praesepe.

The first person to see the Praesepe up close was none other than Galileo Galilei, whose pioneer telescopic exploits we're celebrating in this International Year of Astronomy. Galileo was the ultimate beginner. No one before him had plied the heavens with a telescope. Everything he saw — craters on the Moon, the phases of Venus, Jupiter's moons — was new and wondrous.

With no preconceived idea of what he was about to see, the Italian astronomer must have been as surprised and delighted by the Praesepe's telescopic appearance as I was. In *Sidereus Nuncius* ("Starry Messenger"), published in 1610, Galileo wrote that the Praesepe "is not a single star but a mass of over forty starlets."

Modern-day astronomers have added several hundred cluster members to the 40 that Galileo saw. Eighty are brighter than 10th magnitude, including 15 between magnitude 6.3 and 7.5. With an overall magnitude of 3.1, M44 outshines any of Cancer's stars. Because the Beehive stretches across 1.6° of sky (the width of 3 Full Moons), it begs to be viewed with binoculars or a rich-field telescope. This is one deep-sky object that fares better in small scopes than in refrigerator-sized Dobsonians!

A group of 6th- and 7th-magnitude stars that outline what bears resemblance to a traditional beehive dominates the central part of the Beehive. We can assume the surrounding stars represent a swarm of heavenly bees. The hive's peak is South 571, an eye-catching triple star that English astronomer Sir James South catalogued in 1825. It's also known as Burnham 584, after the American double-star observer S.W. Burnham who added a 12th-magnitude star to the mix in 1878.

If you're an astronomical neophyte, go out tonight and "discover" the Beehive Cluster. As for you veterans who have been around the galaxy awhile, take a break from those 14th-magnitude planetary nebulae! Get out your binoculars or rich-field telescope and spend a few minutes rediscovering this gem. You're guaranteed to get a cosmic buzz!

My reference to a Gilbert telescope in the opening paragraph might bring back fond memories to some of you old-timers. For a nostalgic look at this classic scope, sold by the A.C. Gilbert Company in the 1950s and 1960s, check out Uncle Rod Mollise's blog (http://uncle-rods.blogspot.com; click on his March 2007 entry).

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: A peek through Galileo's telescope. Clear skies!

INDEX *of* ADVERTISERS

Adirondack Video Astronomy 73
Adorama 9, 25
Anacortes Telescope & Wild Bird 72, 73
Aridian Publishing 82
Ash Manufacturing 71
Astro Haven 4
Astro-Physics 71
Astronomics 15, 71
Astronomy magazine 12
Astronomy special issue 69
Astronomy Technologies 71
Astronomy.com 73, 75
AstroTelescopes 72
Beam of Light Technologies 72
Cambridge University Press 17
Celestron 67
Daystar Filters 27
Denkmeier Optical 73
Equatorial Platforms 73
Glatter Howard 73
Hotech Corp 72
Into the Wind-The Kite Source 73
Jewelry Designs For Men 72
Jim's Mobile, Inc 27
Khan Scope Centre 72
Let's Talk Stars 73
Lightbuckets 17
Lumicon 23
Mayhugh Travel 27
Meade Instruments Corporation 2-3
New England Astronomy & Telescope 71
New Mexico Southern Skies 71
Nitescapes 3-D Productions 72
Northeast Astronomy Forum 4
Observatory, Inc., The 72
Oceanside Photo & Telescope 67
Optic Wave Laboratories 72
Optical Mechanics, Inc 71
Orion Telescopes & Binoculars 7
Owl Services 72
Pegasus Optics 72
Rainbow Symphony 72
Scope Buggy 72
ScopeStuff 72
SCS Astro 73
Seymour Solar 73
Solarscope 72
Starizona 4
Stellarvue 72
Technical Innovations 27
Tele Vue Optics, Inc. 73
The Teaching Company 13
TheSecretDoorway.com 72
Vixen Optics 81
William Optics Co. 72
Woodland Hills Camera & Telescope 17
www.bigbinoculars.com 73

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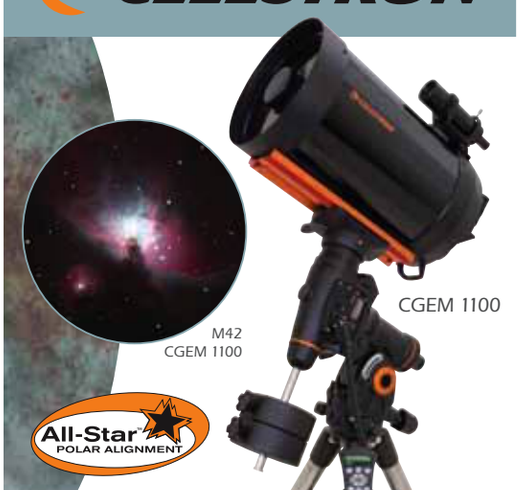

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Binocular Universe

by Phil Harrington

Comb through Coma Berenices

Spend a clear night with three of the constellation's binocular targets.

I like to take advantage of just about every clear night we get this time of year. In my neck of the woods, they can come few and far between. The old adage of April showers bringing May flowers is alive and well in the Northeast, as April is traditionally one of the cloudiest and wettest months of the year.

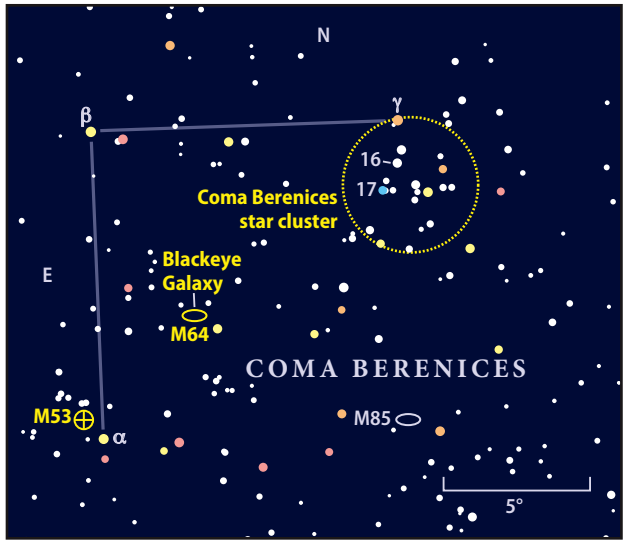
One of the reasons I'm so keen to observe the April sky is the **Coma Berenices star cluster** (Melotte 111), which is among my favorite binocular targets. To find the cluster in its namesake constellation, Coma Berenices (Bernice's Hair), aim toward the center of the large "empty" area framed by the constellations Boötes the Herdsman to the east, Leo the Lion to the west, and the arc of the Big Dipper's handle to the north. Scan back and forth slowly until you bump into a wedge-shaped group of stars that will nearly fill the field of your binoculars. That's the Coma star cluster. In fact, if you view from a dark site, you can see the Coma star cluster as a fuzzy patch of light without using any optical aid.

That misty appearance quickly dissolves into myriad points of distant starlight through even the smallest binoculars. The brightest stars fall into a pattern resembling the Greek letter Lambda (λ) (if you're viewing from south of the equator, Gamma [γ]).

Once you find the cluster, sit back and examine it carefully. You might notice that the star at the Lambda's northern tip, 4th-magnitude Gamma (γ) Comae, has an orangish glow. Gamma is a spectral type K orange giant star that is just starting to evolve off the main sequence. Knowing the spectral classes of these stars allows astronomers to estimate the age of clusters. In this case, scientists estimate the Coma cluster to be only about 400 million years old.

Follow the eastern side of the Lambda southward to 16 Comae. Binoculars show three faint companions surrounding it, standing at attention as if guarding a precious jewel.

Farther southeast, the binary star 17 Comae is easy to resolve through binoculars. This pair of white-hot stars appears separated by more than 2', which is wide enough to resolve even through modest 6x field glasses.



Coma Berenices is a poorly defined constellation with only three stars brighter than magnitude 4.5, but it is home to one of the author's favorite binocular targets — the Coma Berenices star cluster (Melotte 111). *Astronomy*: Roen Kelly

Scanning the rest of the constellation, our next stop is globular cluster **M53**. M53 proves a tough test for any binoculars smaller than 60mm in aperture. Finding it is simple enough, however. From brilliant Arcturus (Alpha [α] Boötis), head west to Eta (η) Boötis. Eta is often shown as forming the "tail" of the Boötes "kite."

Continue westward to 4th-magnitude Alpha Comae. M53 is less than 1° northeast of Alpha. Look for a round, hazy disk, like a small interstellar ball of cotton set in a star field.

Coma Berenices probably is best known for its wealth of distant galaxies. Unfortunately, most are beyond the grasp of binoculars. One that stands out from the rest, however, is M64, the famous **Blackeye Galaxy**.

To find it, slide about half a field of view due west of Alpha Comae to the reddish star 36 Comae, and then move northwest to 35 Comae. M64 is just to 35 Comae's northeast. With 50mm binoculars, you may glimpse this 8th-magnitude galaxy as an oval patch of light.

Viewing through 20x80 or larger binoculars, you also might spot the "black eye," a dark lane of dust clouds silhouetted in front of one of the Blackeye Galaxy's spiral arms. Interestingly, this lane seems to mark a boundary separating two counter-rotating sections of the galaxy. Studies suggest that this bizarre situation is the aftermath of a collision between a small galaxy and a large galaxy that is still settling down.

Subscribers, join me on Astronomy.com this month for a few other binocular targets in and around Coma Berenices, as well as a link to a free binocular observing guide.

Questions, comments, suggestions? E-mail me at phil@philharrington.net. Until next month, when we head to the deep south, remember that two eyes are better than one!

Find more Coma Berenices targets at www.Astronomy.com/toc.

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[w] www.astrodon.com

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Staten Island, New York

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Price: $99.95
[t] 888.291.6577
[w] www.smartastronomy.com

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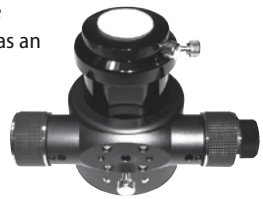

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[f] 407.324.0105
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The Magnitude Mat

Orion Telescopes and Binoculars
Watsonville, California

Orion's screen-printed mat protects your knees when you're kneeling at the telescope. The mat is closed-cell foam rubber with a cutout handle and is water and compression resistant. It measures 21" by 14" by 1" (53cm by 36cm by 2.5cm).

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[t] 800.447.1001
[w] www.telescope.com

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Meade Instruments
Irvine, California

Meade's ETX-LS with LightSwitch Technology f/10 Schmidt-Cassegrain telescope performs all setup functions with the flip of a switch. The AutoStar III hand controller gives you access to 100,000 celestial objects.

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Light shroud for SkyQuest XX12

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Orion's SkyQuest XX12 Truss Tube Dobsonian Light Shroud blocks stray light and lessens the accumulation of dust and dew on the XX12 Dobsonian's primary mirror. The shroud is opaque-black stretch nylon that fits over the XX12's truss poles.

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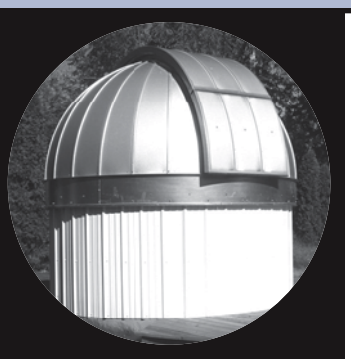
Price: $699.95
[t] 800.447.1001
[w] www.telescope.com

Tele Vue Paracorr Tunable Top

Orion Telescopes and Binoculars
Watsonville, California

This observing accessory optimizes the correction amount by adjusting the eyepiece distance from a Tele Vue Paracorr, which corrects for coma, an optical defect that smears star images. Loosen a screw and rotate the Tunable Top to change the eyepiece barrel height.

Price: $70
[t] 800.447.1001
[w] www.telescope.com



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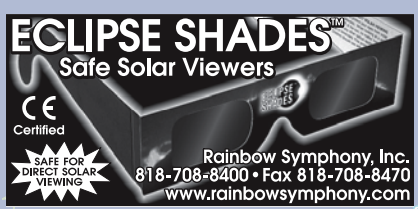

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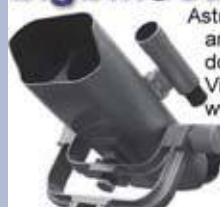

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ADIRONDACK Astronomy

by Michael E. Bakich

Peter **Moreo**

President, Orion Telescopes & Binoculars

Editor's note: Welcome to the first installment of "Telescope Insider." Here, each month, we'll give you a behind-the-scenes look at one person who drives the astronomy hobby industry.

Peter Moreo is new to telescopes, but he's an expert at how successful companies market their products. He took the reins of Orion in September 2007, and since then, besides learning everything he could about observing, he's led the company in introducing several major products.

Moreo, originally from Seattle, earned degrees in economics and history from Whitman College in Walla Walla, Washington, and received his M.B.A. from the University of Southern California. Since then, he's worked in the consumer electronics industry. Before arriving at Orion, he was the Director of Sales and Merchandising for Hewlett-Packard's consumer online store for 6 years.

Peter Moreo shows off his favorite scope, the new SkyQuest XX12 Intelliscope Truss Dobsonian.

What are Orion's most popular models?

Right now, six of our products are really hot. Our newest is the SkyQuest XX12 Intelliscope Truss Dobsonian. Of course, when you launch a new product, you have expectations. Pre-orders for the XX12 exceeded them. [Editor's note: Look for a SkyQuest XX12 review in an upcoming issue.]

We recently launched our Starblast 6 Astro Telescope as a step up from our existing Orion Starblast 4.5. Rather than me commenting, I'll quote *Astronomy*'s January 2009 review: "Relatively inexpensive and easy to operate, the Starblast 6 would make a worthy telescope for the beginner. If you are an experienced amateur astronomer, you'll appreciate this scope. …" [Find the complete review at www.Astronomy.com/toc.]

Recently, Orion entered the astroimaging scene in a major way. Our StarShoot AutoGuider and Orion StarShoot Pro Deep Space Color CCD Camera were two new entries in 2008. Along with our Premium 190mm f/5.3 Mak-Newt Optical Tube and EON 120mm ED Apo Refractor Telescope, these products are critical parts of our imaging solutions.

What is something cool about Orion that nobody really knows?

As part of our industry commitment, we expect to test-launch the Orion Educational Program during the first quarter of 2009. We're still working on the pilot, so I don't have details to share.

How has Orion changed through the years?

Orion began operating in 1975, but I won't go that far back. I can think of four recent major changes. The first was Orion's sale to Imaginova in 2004, which has had a positive impact on our business.

The second change involved a product. The launch of the Orion StarShoot Deep Space Color Imager was the catalyst for Orion getting into the affordable imaging category. This area has quickly grown into a major part of our business.

The third change was the re-launch of our ecommerce platform in October 2007. Internally, this reaffirmed that we would remain a strong direct marketer with an emphasis on Orion's traditional catalog business as well as ecommerce.

> *"Folks like to 'look up and wonder,' and as long as that is true,* ***I think our hobby has a bright future."***

The fourth change would be the recent launch of the XX12, which reaffirms our Dobsonian roots and our intent to develop new products in this category.

Do you enjoy observing?

My family and I are new to the hobby. Our first scope purchase was the Starblast 6. Also, we have quite a few scopes floating around at the office, so I have been fortunate to test-drive a number of different kinds. My new favorite is the XX12.

Can you break some news about upcoming products?

Our business policy is that we do not comment on future products. However, given *Astronomy*'s special request, I am willing to make this one exception for your readers. Our customers will see exciting design, functionality, and size developments in our Dobsonian lines (XX14 and more?).

Where, in your opinion, is the hobby headed?

In the short-term, the current economic turmoil is going to have a dampening impact on most hobbies, and unfortunately, our industry is going to get caught up in that slowdown. With that said, folks like to "look up and wonder," and as long as that is true, I think our hobby has a bright future.

6 hottest current Orion products:

- SkyQuest XX12 Intelliscope Truss Dobsonian
- EON 120mm ED Apo Refractor Telescope
- StarShoot AutoGuider
- StarShoot Pro Deep Space Color CCD Camera
- Premium 190mm f/5.3 Mak-Newt Optical Tube
- Starblast 6 Astro Telescope

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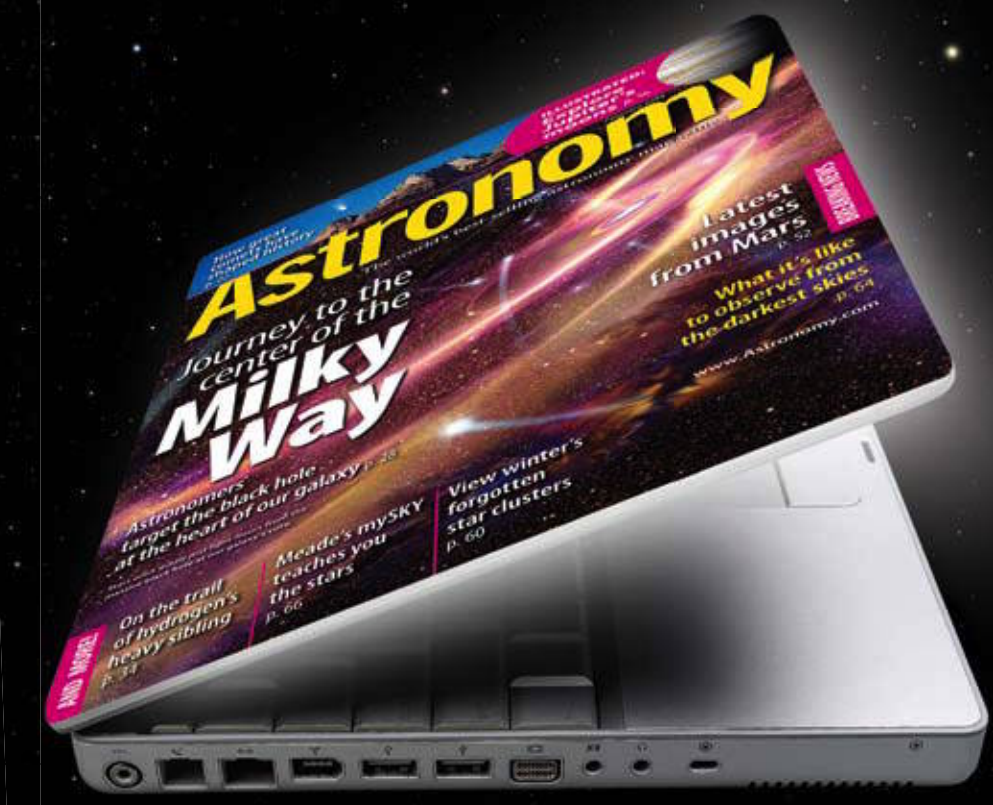
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reader gallery

The Dumbbell Nebula (M27) (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.1, Santa Barbara Instrument Group STL-11000 CCD camera, Astrodon 3-nanometer Hα, OIII, and NII filters, image comprises 1-hour exposures through each filter) • Don Goldman, Orangevale, California

Sharpless 2–104 in Cygnus is small but bright. Good thing, because it lies in a vast field of nebulosity. Sh 2–104 also has great structure. (Intes Micro 8-inch Maksutov-Newtonian telescope at f/4, SBIG ST-10XME CCD camera, HαRGB image with exposures of 360, 75, 75, and 75 minutes, respectively) • Dean Salman, Tucson, Arizona

A whole new light

The shot (above) of the Dumbbell Nebula (M27) in Vulpecula is the first Reader Gallery image taken through a Nitrogen-II (NII) filter. Don Goldman, astro-imager and president of AstroDon filters, developed the NII filter to distinguish between nitrogen emission and that of Hydrogen-alpha (Hα). Most Hα filters have bandpasses great enough to include NII wavelengths. By separating Hα and NII data with narrower bandpass filters, the resulting image shows detail in the central region thought to come from Hα emission, but which actually originates with nitrogen.

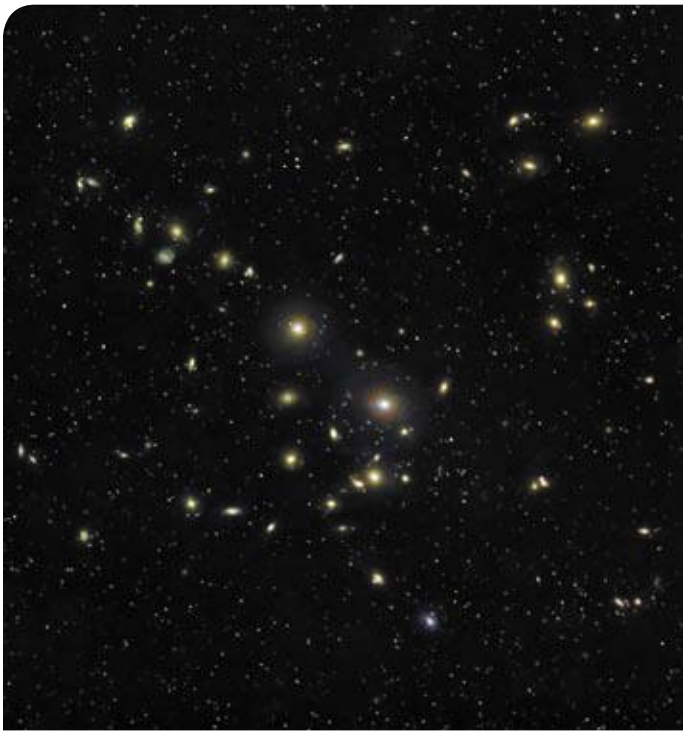
Reflection nebula M78 in Orion is not a bright object visually, but long-exposure images capture its amazing color and details. (8.25-inch Astro-Physics apochromatic refractor at f/8, Apogee Alta 16803 CCD camera, LRGB image produced by stacking five 15-minute exposures through each filter) • Tony and Daphne Hallas, Foresthill, California

reader gallery

The Moon and Mercury hung in the morning sky last fall. Mercury, at magnitude –0.8, floated 7° north-northeast of the Moon. (Canon 10D digital SLR, 40mm f/4.5 lens set to f/5.6, ISO 400, 1-second exposure taken October 27, 2008, at 6 A.M. MDT) • Chris Schur, Payson, Arizona

Interacting galaxies NGC 1316 (left) and NGC 1317 in Fornax give rise to the radio source known as Fornax A. NGC 1316 shines at magnitude 8.4, and NGC 1317 glows at magnitude 10.8. (RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-11000 CCD camera, LRGB image with exposures of 105, 36, 36, and 36 minutes, respectively) • Daniel Verschatse, Observatorio Antilhue, Chile

Maffei 1 and Maffei 2 are small, faint targets that reside in Cassiopeia. Maffei 1 is the nearest giant elliptical galaxy to the Milky Way. Maffei 2 is a barred spiral galaxy. (3-inch Borg 77 apochromatic refractor at f/6.5, Canon 5D digital SLR, 70-minute exposure) • Jack Newton, Portal, Arizona



The Perseus galaxy cluster has the giant elliptical galaxy Perseus A (NGC 1275) as its centerpiece. The cluster contains some 500 member galaxies. (12.5-inch Planewave CDK telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 300, 80, 80, and 80 minutes, respectively) • Kent Wood, Folsom, California

Open cluster M36 in Auriga shines at magnitude 6 and sits 6° north-northeast of Elnath (Beta [β] Tauri). M36 measures 12' in diameter. (4-inch Tele Vue NP101 apochromatic refractor at f/5.4, ST-2000XM CCD camera, LRGB image with exposures of 72, 64, 32, and 32 minutes, respectively) • Bernhard Hubl, Schlierbach, Austria

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

The Gabriela Mistral Nebula (NGC 3324) in Carina resembles the Nobel Prize winning Chilean poet who was born and raised near the current sites of Cerro Tololo, Cerro Pachon, and Cerro Morado observatories. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, Apogee Alta 16803 CCD camera, Hα/SII/OIII image with exposures of 240, 150, and 150 minutes, respectively) • Ken Crawford, Camino, California

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Optical Design Reduces Dewing	Yes	No	No
VISAC System- Vixen Sixth Order Aspherical Catadioptric	Yes	No	No
Mount Options	12	5	2
Warranty Period	5 Years	2 Years	1 Year
Manufactured	Japan	China	Mexico

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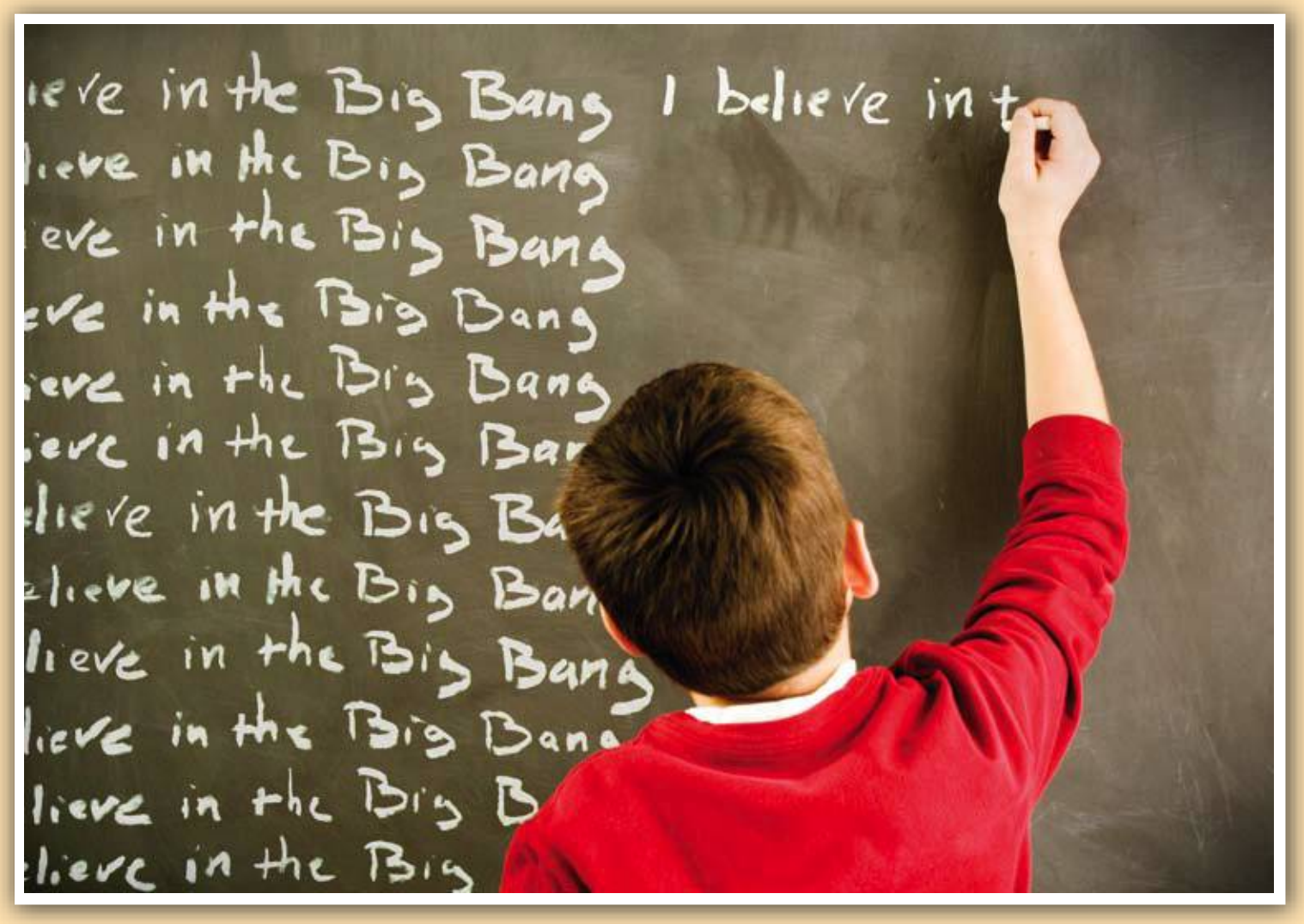

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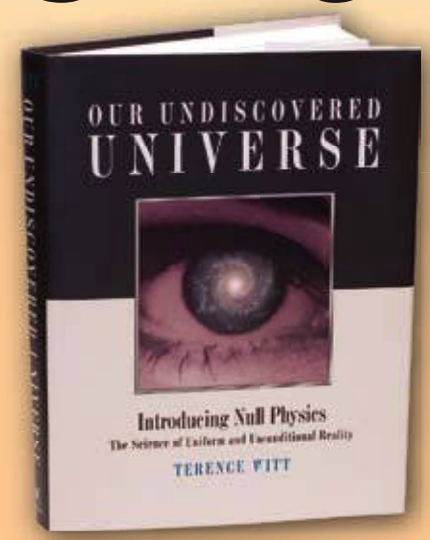

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